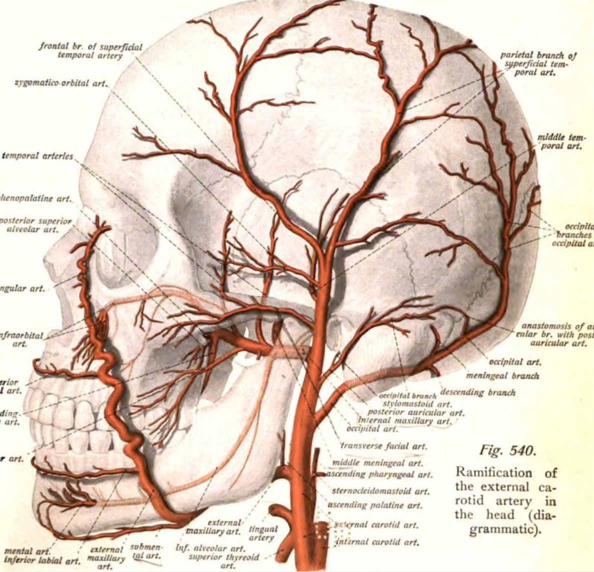

Fig. 540.

Ramification of the external carotid artery in the head (diagrammatic).

Atlas and Text-book of Human Anatomy,: Vascular system, ...

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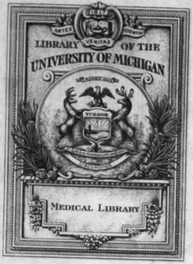
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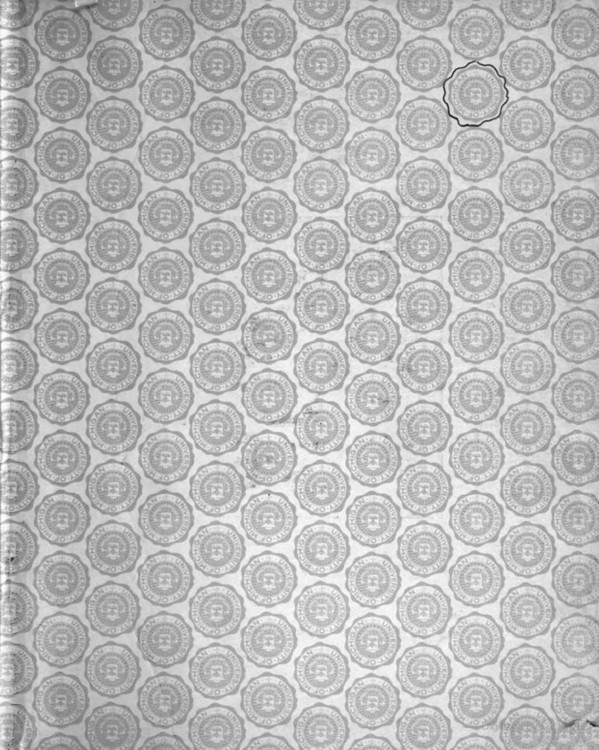
UNIVERSITY OF MICHIGAN

ATLAS AND TEXT-BOOK

OF

HUMAN ANATOMY

BY

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VOLUME III

VASCULAR SYSTEM, LYMPHATIC SYSTEM, NERVOUS SYSTEM AND SENSE ORGANS

With 297 Illustrations, Mostly in Colors

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PREFACE

The following third and last volume of this Atlas includes the remainder of the vascular system and the entire nervous system, together with the organs of special sense.

Long years of experience in the dissecting-room have led the author to depict the peripheral nerves and blood-vessels as the student is accustomed to see them in the cadaver, *i. e.*, the vessels and nerves together in the same region. Consequently, as a rule, the arteries and nerves, or the arteries, veins and nerves, or the arteries and veins, have been shown in the same illustration, and this rule has been departed from only in those instances where, for the sake of clearness (in the case of the cerebral nerves, for example), complementary pictures with the nerves or arteries alone have been added.

This arrangement of the material has the advantage that the student using the atlas in the dissecting-room can find upon a single page the great majority of the structures found in a layer of his dissection and is not forced to hunt through the volume and waste much time in unnecessary search. At the same time, the reader of the book receives in this manner a series of composite topographic illustrations.

A reproduction in colors was rendered absolutely necessary by the simultaneous representation of the blood-vessels and nerves. In the interest of special differentiation the arteries were consequently colored red, the veins blue, and the nerves bright yellow. For the production of the colors, as for the production of all the plates in the volume, half-tones were employed, which have been faultlessly prepared by the well-known Vienna firm of Angerer & Göschl. The yellow, red, and blue plates were at the same time made use of for the coloration of the remaining tissues in the illustrations (muscles, bones, fat, skin, etc.), and in this manner colored illustrations were obtained which are most comprehensive, and, although not absolute reproductions of the dissections, they correspond in a schematic manner in the colorings of the different tissues. All the illustrations in this Atlas were prepared from original drawings by K. Hajek, who has again demonstrated his artistic talent and cleverness in the representation of anatomical structures.

As previously mentioned in the Preface to the first volume, the chief aim of the author has been to produce a useful book for the medical student and the physician, rather than an atlas for the finished anatomist. He who wishes to pursue more advanced work along special lines will be forced to consult special works and would find this Atlas insufficient were it to contain twice as much. The great size of such a work and the burdensome number of special dissections would be of interest only to the expert anatomist, and would serve rather to confuse the student and the physician and render it more difficult for them to find what they need. My main purpose was, therefore, to limit myself to the most necessary data and to arrange these in a series of com-

posite pictures which would be as comprehensive as possible. In the representation of the central nervous system and its fibers great care has been exercised, since my experience has been that too much material is confusing rather than instructive, especially since it might be necessary in a short time to make many alterations on account of changes in opinion dependent upon the progress of investigation.

The majority of the preparations from which the illustrations were made have been dissected by myself especially for this work, although other complementary dissections have occasionally been introduced. The greater number of the illustrations are exact reproductions of the dissections; minor accidental variations have usually been represented, since they are frequently found by the student himself, but the more striking anomalies have been corrected by comparative dissections. Some of the illustrations have been drawn from specimens in the anatomical collection of the Würzburg Institute, and for permission to utilize this material I am greatly indebted to Professor Stöhr.

THE AUTHOR.

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ATLAS AND TEXT-BOOK

OF

HUMAN ANATOMY.

THE ARTERIES.

THE arteries of the body may be divided into those of the pulmonary circulation and those of the systemic circulation. Each system originates in a single arterial trunk, that of the greater or systemic circulation being known as the *aorta* (see Vol. II, page 167), while that of the lesser or pulmonary circulation is the *pulmonary artery* (see Vol. II, page 167).

The Development of the Arterial System.—The primitive embryonic heart gives off but a single arterial tube, the *truncus arteriosus*, which subsequently divides into two primitive aortæ, each forming an arch with its convexity directed toward the head. Each arch consists of an ascending ventral limb, originating from the truncus arteriosus, and a descending dorsal limb, which unites with its fellow of the opposite side to form the primitive descending aorta.

Between the ventral and dorsal limbs of the primitive aortic arches transverse connections, known as the branchial arteries, develop. They are five in number upon each side,* each branchial artery being situated in a visceral arch, and they early become developed to such an extent that the limbs of the original aortic arches soon appear to be mere connections between them. Both the permanent aortic arch with its branches and the pulmonary artery are developed from the branchial arteries, some portions of which, together with their connections, persist, while others disappear. Thus the fourth pair of branchial arteries and their dorsal connection with the fifth are retained and form the permanent aortic arch upon the left side, and the innominate artery and proximal portion of the subclavian upon the right. The third pair also persist as the connections between the internal and external carotid arteries, their ventral connections with the fourth pair forming the common carotids, while the first and second pair completely disappear, as do also the dorsal connections between the third and fourth pair of vessels. The ventral connections of the third and second and second and first vessels become the external carotids, while the corresponding dorsal connections form the internal carotids. The right fifth arch disappears, the left becomes the ductus arteriosus.

The truncus arteriosus by its longitudinal division (see Vol. II, page 180) gives rise to the permanent aorta and the pulmonary artery, the latter having connected with it the fifth pair of branchial arteries. From each of these a branch passing to the lungs develops, and the portion of the right artery between the branch and the right aortic arch disappears, while the corresponding portion of the left artery persists until birth as the ductus arteriosus. Finally, the portion of the right aortic arch below the point where it gives off the distal portion of the subclavian artery disappears, the left arch persisting in its entirety to form the portion of the permanent aortic arch, distal to the origin of the innominate artery.

* [A rudimentary sixth branchial artery probably occurs, intervening between the fourth and fifth, as enumerated above, but since it takes no part in the formation of the permanent vessels and remains rudimentary, it may be disregarded in what follows. —ED.]

THE PULMONARY ARTERY.

The pulmonary artery (Figs. 447, 448, 455, 518, 519, and 521), 5 to 6 cm. in length, is a wide but rather thin-walled tube, which arises from the conus arteriosus of the right ventricle of the heart. Its origin is situated in front of the aorta, between the tips of the two auricles, and it passes upward, backward, and to the left at the left side of the ascending aorta, both vessels being enclosed within the pericardium and invested by the epicardium (see Vol. II, page 181), and united by firm fasciculi of connective tissue. After penetrating the pericardium and reaching the level of the fourth thoracic vertebra the pulmonary artery divides beneath the aortic arch into a right and a left branch, which pass to their respective lungs. The division takes place just as the pulmonary artery emerges from the pericardium, so that the inferior aspects of both branches are invested with epicardium for a short distance.

Each branch runs almost transversely to the hilus of its lung, but each holds a different relation to the neighboring great vessels, particularly to the aorta. The right branch is somewhat longer and larger than the left and passes behind the ascending aorta and the superior vena cava; the smaller and shorter left branch, however, is situated in front of the descending aorta.

Before entering the hilus of its lung each pulmonary artery subdivides, the branches in general being associated with the bronchi and the subsequent smaller divisions following the bronchial ramifications. These subdivisions of each pulmonary artery, together with their corresponding veins and the bronchus, constitute the so-called root of the lung (see Vol. II, page 102). The entrance into the hilus takes place in such a manner that the branches of the left pulmonary artery are all placed above and in front of the corresponding bronchial rami, while, upon the left side, an eparterial bronchus passes to the lung above the branches of the right pulmonary artery (see Vol. II, page 103).

Before birth the *ductus arteriosus (Botalli)* forms a pervious branch of the pulmonary artery, but in the adult it is represented by a slender fibrous band, the ***ligamentum arteriosum***, which connects the bifurcation of the pulmonary artery with the concavity of the aortic arch, the aortic attachment being situated at the dividing line between the aortic arch and the descending aorta. The duct is patulous until birth and forms the direct continuation of the left pulmonary artery (see Vol. II, page 169), while the permanent right and left pulmonary arteries are nothing more than subsidiary branches up to the time of birth.

The branches of the pulmonary arteries ramify in the lungs and pass over into a very dense and fine-meshed capillary network which gives origin to the radicals of the pulmonary veins. The pulmonary arteries carry venous blood, poor in oxygen and rich in carbon dioxid, which is arterialized in the lung—*i. e.*, it gives off carbon dioxid and takes up oxygen.

THE AORTA.

The aorta is the single, principal trunk of the systemic arterial system, and gives origin either directly or indirectly to all of its arteries. Its wall is considerably thicker than that of the pulmonary artery and appears intensely yellow in the fresh state on account of its richness in elastic tissue. The aorta consists of a short ascending portion, the *ascending aorta;* of a curved middle portion, the *arch of the aorta;* and of a long descending terminal portion, the *descending*

aorta. It arises from the aortic orifice of the left ventricle, behind the pulmonary artery, and terminates in front of the body of the fourth lumbar vertebra. Throughout its course its caliber constantly diminishes.

The descending aorta is further subdivided into two parts, which are demarcated by the diaphragm. That portion situated above the diaphragm is known as the *thoracic aorta*, while that portion below the diaphragm and within the abdominal cavity is called the *abdominal aorta*.

The distribution of the principal branches of the aorta is as follows: The ascending aorta gives off only the *coronary arteries*, which supply the heart itself with nourishment; the aortic arch furnishes the large arterial trunks for the upper half of the body, the *innominate artery* upon the right side and the *left common carotid* and *left subclavian arteries* upon the left. The only large branches of the thoracic aorta are the *intercostal arteries*. The abdominal aorta, however, gives off numerous branches, some of which are quite large, especially those passing to the abdominal viscera (the *cœliac*, the *superior mesenteric*, the *inferior mesenteric*, the *renals*, the *suprarenals*, and the *internal spermatics*); the smaller branches pass to the abdominal parietes (the *inferior phrenics* and the *lumbars*). The arterial trunks for both lower extremities, the *common iliac arteries*, arise from the aortic bifurcation itself, and in addition almost throughout the entire length of the aorta numerous quite small branches are given off to the adjacent tissues.

THE ASCENDING AORTA.

At its origin from the heart, behind the commencement of the pulmonary artery, the ascending aorta (Figs. [illegible], 533 to 538, and 588) exhibits a distinct enlargement, known as the *aortic bulb*. In this situation are found three shallow expansions of the aortic wall which correspond to the three semilunar valves (see Vol. II, page 180) and are called the *aortic sinuses* (*sinuses of Valsalva*). The aorta then passes upward and to the right, on the right side of the pulmonary artery and behind the manubrium and the body of the sternum, and has to the left and somewhat in front of it the superior vena cava, so that it is midway between the latter vessel and the pulmonary artery. The right branch of the pulmonary artery, the right pulmonary veins, and the right bronchus are behind the ascending aorta. Almost the entire length of the ascending aorta is within the pericardium, and its origin is partly concealed behind the right auricle (Fig. 533).

According to the individual breadth of the sternum the ascending aorta is situated either completely behind that bone or extends slightly beyond its right sternal margin. The latter condition obtains especially in the second intercostal space, particularly in advanced life, as a result of a distinct dilation (the great aortic sinus) of the aorta at the point where the impact of the blood-stream coming from the heart is received.

The only branches of the ascending aorta are the coronary arteries of the heart (Figs. 536 and 537), which arise from the left and right aortic sinuses. These vessels are of moderate size and are intended solely for the nourishment of the heart, especially of the cardiac musculature.

1. The *left coronary artery* of the heart arises from the left aortic sinus and is situated in the coronary sulcus, at first behind the root of the pulmonary artery. Either in this situation or close beside the root of the pulmonary artery it subdivides into its two terminals, the *anterior descending branch* and the *circumflex branch*. The circumflex branch runs in the coronary

FIG. 536.—The arteries and veins of the heart as seen from in front (sternocostal surface).

A portion of the conus arteriosus and of the commencement of the pulmonary artery has been cut away in order to show the origin of the left coronary artery.

FIG. 537.—The arteries and veins of the heart as seen from behind and below (diaphragmatic surface).

---

sulcus in the same direction as the parent trunk, passing between the left auricle and the left ventricle toward the diaphragmatic surface of the heart, and giving off branches to the left atrium and ventricle. The anterior descending branch runs downward in the anterior longitudinal sulcus toward the cardiac apex and ramifies over both ventricles.

2. The *right coronary artery* of the heart (Figs. 536 and 537) arises from the right aortic sinus and runs in the right half of the coronary sulcus toward the diaphragmatic surface, giving off branches to the right atrium and ventricle. One of its terminal branches is of fair size and is known as the ***posterior descending branch;*** it passes downward in the posterior longitudinal sulcus.

The two coronary arteries are connected only by small precapillary ramifications; larger anastomoses do not occur.

The Arch of the Aorta.—The arch of the aorta (Figs. 518, 538, and 588) gives origin to the largest branches of the entire aortic stem, and the caliber of the vessel consequently diminishes rapidly in this situation. The convexity of the arch is directed upward and the concavity downward, and the arch is placed obliquely in the thoracic cavity, since at its commencement at the ascending aorta it is directed anteriorly and to the right, while its terminal portion at the descending aorta inclines posteriorly and to the left. The root of the left lung is situated in the concavity of the arch and the bifurcation of the trachea is behind it, the highest point of the convexity corresponding to the level of the body of the third thoracic vertebra. The sharply curved commencement of the arch lies behind the manubrium and (in childhood) behind the thymus; the markedly narrower and flatter left extremity is situated at the left margin of the body of the fourth thoracic vertebra, and at its transition to the descending aorta there is usually a narrowing of the aortic tube, forming what is termed the *aortic isthmus.*

The branches of the aortic arch are subdivided into those which arise from its convexity and those which take origin from its concavity or from its posterior wall. The latter are quite small and insignificant branches for individual viscera of the thoracic cavity; the former, however, are the large arterial trunks for the upper half of the body. Upon the two sides of the body the arrangement of the vessels differs considerably, since the arteries for the right half of the head and neck and for the right arm spring from a common trunk, the ***innominate artery,*** while the corresponding parts upon the left side are supplied by the ***left common carotid*** and ***left subclavian arteries,*** which arise separately from the aortic arch.

Although this is the normal arrangement of the branches of the aortic arch, deviations in the order of origin are not infrequently encountered, leading either to an increase or a diminution in the number of the branches. The most frequent anomalies may almost without exception be easily explained from the mode of the development of the arterial system (see page 17) and are as follows:

1. The right common carotid and subclavian arteries arise directly from the aortic arch instead of from the innominate artery.

2. The left vertebral artery arises directly from the arch of the aorta.

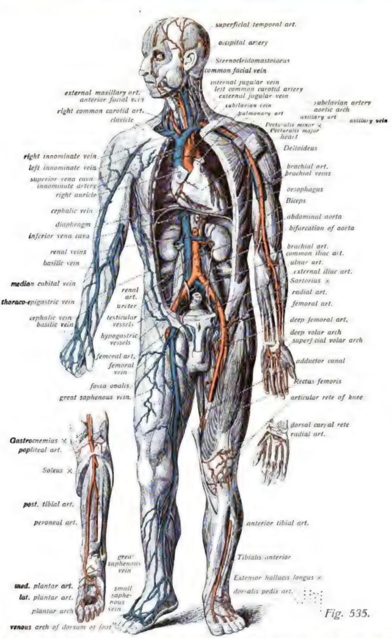


Fig. 535.

Fig. 535. The superficial blood-vessels in the male (diagrammatic). The venous system is shown on the right side (the superficial veins of the extremities being shown); the arterial system on the left. The small figure at the left shows the deep arteries of the leg: that at the right the arteries of the back of the hand.

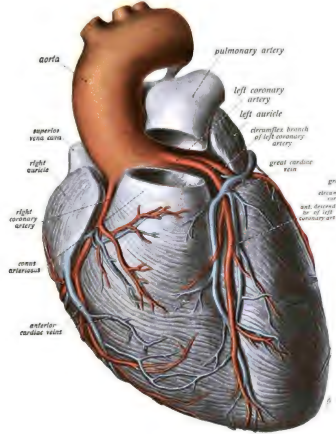


Fig. 536.

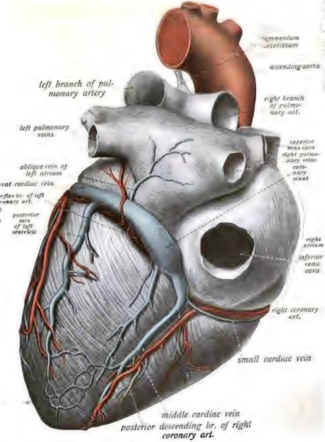


Fig. 537

3. The left common carotid artery is given off from the innominate artery, which thus gives origin to three vessels. In this case but two large branches arise from the aortic arch.

4. There is also an innominate artery upon the left side (very rare).

5. A single thyreoidea ima artery passes upward in front of the trachea or an internal mammary artery arises directly from the aortic arch. The former is an exceedingly rare occurrence, the thyreoidea ima more frequently arising from the innominate artery and even more rarely from the common carotid.

6. The two common carotid arteries unite to form a median innominate trunk (very rare).

7. The right subclavian artery arises beyond the left subclavian artery and must consequently pass the median line and cross behind the œsophagus to reach the right side of the body.

THE INNOMINATE ARTERY.

The *innominate artery* (Figs. 369, 451, 452, 538, and 588) is a thick tube 2.5 cm. in length, which arises from the commencement of the aortic arch almost in the median plane of the body (or even somewhat to the left of it). It is situated behind the manubrium sterni and divides behind the right sternoclavicular joint into its two terminals, the *right common carotid* and the *right subclavian arteries*, the innominate being the artery for the right side of the head and neck and for the right upper extremity. It crosses the trachea at an acute angle, being in front of this structure below, and to the right above, and it is itself crossed by the left innominate vein which is placed in front of it, while the right innominate vein is situated to the right. The right vagus nerve is also found to the right of the innominate artery.

With the exception of its two terminals the innominate artery usually gives off no branches, although it may occasionally give rise to a *thyreoidea ima*.

THE COMMON CAROTID ARTERY.

The origin of the *common carotid artery* (Figs. 451, 452, 538, 539, 550, 552, 588, 700, and 701) varies upon the two sides, inasmuch as the right artery arises from the innominate, while the left is given off directly from the aortic arch. The right common carotid artery is consequently shorter than the left. The latter vessel arises from the convexity of the aortic arch at about its middle and runs upward upon the left side of the trachea behind the left innominate vein. Throughout the remainder of its course it holds relations identical with those of the artery upon the right side.

Each common carotid artery passes through the superior thoracic aperture behind the sternoclavicular articulation and the origins of the sternohyoid and sternothyreoid muscles. In the neck the artery is situated behind the sternocleidomastoid, the intermediate tendon of the omohyoid, and partly behind the outer portion of the sternothyreoid; to the outer side it is in relation with the internal jugular vein and to the inner side with the trachea and the œsophagus. Behind and to its outer side is the vagus nerve, and in front of it, in addition to the previously mentioned muscles, is the descending branch of the hypoglossal nerve. Behind the artery and separated from it by the deep layer of the cervical fascia are the scalenus anterior, the longus capitis, and the longus colli. The superficial and the deep layers of the cervical fascia form a sheath which encloses the common carotid artery, together with the neighboring internal jugular vein, the vagus nerve, and the descendens hypoglossi, and posteriorly, and in a special compartment of the vascular sheath, the cervical portion of the sympathetic trunk is in relation with the artery.

FIG. 538.—The large vascular and nervous trunks of the posterior thoracic wall as viewed from in front and somewhat from the right.

* = Location of twelfth rib. ** = Communication between azygos and hemi-azygos veins.

FIG. 539.—The nerves and arteries of the deeper layer of the left side of the neck; the nerves and vessels of the subclavicular fossa (fifth layer of neck).

There have been removed: the omohyoideus, the internal jugular vein (at *x x* are seen the upper and lower cross-sections; *x* = cross-section of external jugular). The insertion of the sternocleidomastoideus has been reflected upward and the splenius capitis divided along the line of the occipital artery. * = Thoraco-acromial vein, which has been divided just before its termination in the cephalic vein.

Since the common carotid artery passes almost directly upward it must cross the obliquely placed sternocleidomastoideus; it consequently appears in the carotid fossa at the anterior margin of the muscle. In this location the artery is superficial, being covered only by the cervical fascia and the platysma, and is situated beside the posterior margin of the thyreoid cartilage and the lateral surface of the pharynx. At a variable height, usually at the level of the superior cornu of the thyreoid cartilage, the artery bifurcates into its two terminals, the *external* and the *internal carotid arteries.*

The common carotid artery gives off no other branches, since the territory through which it passes is supplied by the subclavian artery. Only at the site of bifurcation are there some fine capillaries which form a minute vascular plexus, the so-called carotid gland or *glomus caroticum.**

THE EXTERNAL CAROTID ARTERY.

The external carotid artery (Figs. 539 to 543, 550, 551, 591 to 593, 687, 691, 692, 699, and 700) pursues a slightly tortuous course in the same direction as the parent trunk, diminishing rapidly in caliber and passing through the carotid and retromandibular fossæ to the region of the external ear. At the neck of the mandible, in the groove between the root of the external ear and the temporomandibular articulation, it divides into its two terminal branches. In the carotid fossa the artery is superfically placed like the common carotid, and is covered only by the superficial fascia, the platysma, and partly also by the common facial vein. It then passes beneath the posterior belly of the digastricus and the stylohyoideus, and runs between these muscles and the styloglossus to the posterior margin of the ramus of the mandible, being in this part of its course directed somewhat backward and inward, and more or less firmly imbedded in the substance of the parotid gland.

Including the two terminals, the external carotid artery usually gives off nine branches. Five arise in the carotid fossa, the *superior thyreoid*, the *lingual*, the *external maxillary* (facial), the *ascending pharyngeal*, and the *sternocleidomastoid.* The *occipital* and *posterior auricular arteries* arise in the retromandibular fossa, and the two terminals are the *superficial temporal* and the *internal maxillary arteries.*

1. The **superior thyreoid artery** (Figs. 539, 551, 588, 695, 699, and 700) is a fairly large vessel which arises from the anterior surface of the external carotid, almost immediately above

* The only branch which occasionally arises from the common carotid artery is the *thyreoidea ima.* This origin for it is, however, exceedingly rare; usually it arises from the innominate or, in the rarest instances, directly from the aortic arch.

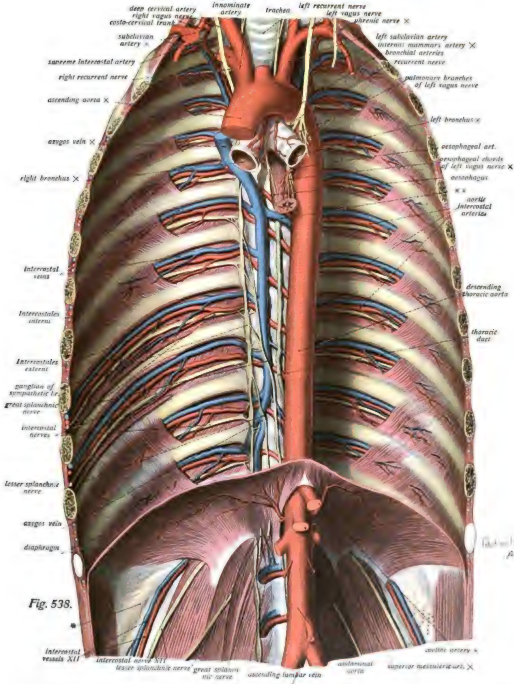
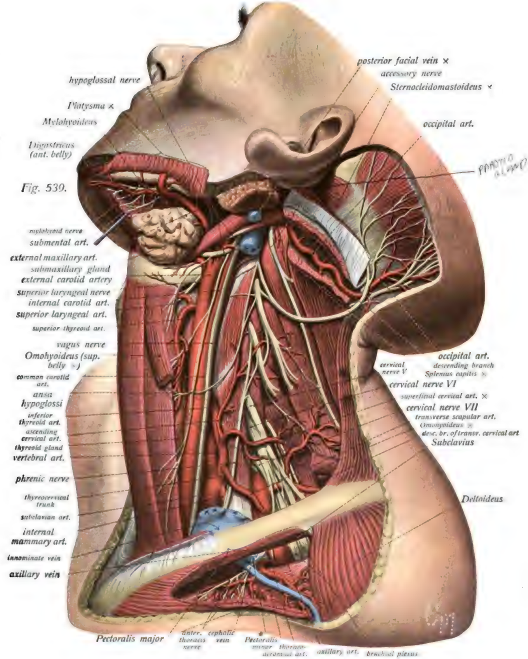

deep cervical artery
right vagus nerve
costo-cervical trunk
innominate artery
trachea
left recurrent nerve
left vagus nerve
phrenic nerve ×
subclavian artery ×
left subclavian artery
internal mammary artery ×
bronchial arteries
supreme intercostal artery
recurrent nerve
right recurrent nerve
pulmonary branches of left vagus nerve
ascending aorta ×
left bronchus ×
azygos vein ×
oesophageal art.
oesophageal chords of left vagus nerve ×
right bronchus ×
oesophagus
××
aortic intercostal arteries
Intercostal veins
descending thoracic aorta
Intercostales interni
thoracic duct
Intercostales externi
ganglion of sympathetic tr.
great splanchnic nerve
intercostal nerves
lesser splanchnic nerve
azygos vein
diaphragm
*
intercostal vessels XII
intercostal nerve XII
lesser splanchnic nerve
great splanchnic nerve
ascending lumbar vein
abdominal aorta
coeliac artery ×
superior mesenteric art. ×

Fig. 538.

Fig. 539.


posterior facial vein ×
accessory nerve
Sternocleidomastoideus ×
occipital art.
PAROTID GLAND
hypoglossal nerve
Platysma ×
Mylohyoideus
Digastricus (ant. belly)
mylohyoid nerve
submental art.
external maxillary art.
submaxillary gland
external carotid artery
superior laryngeal nerve
internal carotid art.
superior laryngeal art.
superior thyreoid art.
vagus nerve
Omohyoideus (sup. belly ×)
common carotid art.
ansa hypoglossi
inferior thyreoid art.
ascending cervical art.
thyreoid gland
vertebral art.
phrenic nerve
thyreocervical trunk
subclavian art.
internal mammary art.
innominate vein
axillary vein
occipital art.
descending branch
cervical nerve V
Splenius capitis ×
cervical nerve VI
superficial cervical art. ×
cervical nerve VII
transverse scapular art.
Omohyoideus ×
desc. br. of transv. cervical art
Subclavius
Deltoideus
Pectoralis major
anter. thoracic nerve
cephalic vein
Pectoralis minor
thoraco-acromial art.
axillary art.
brachial plexus

the bifurcation of the common carotid artery. It is covered by the cervical fascia and platysma and runs through the carotid fossa in what is at first a gentle upward curve, finally passing downward behind the superior belly of the omohyoideus to reach the thyreoid gland. Its branches are:

(*a*) The ***hyoid branch*** (Figs. 539, 699, and 700), a small twig to the anterior surface of the body of the hyoid bone.

(*b*) The ***superior laryngeal artery*** (Figs. 539, 694, 695, 699, and 700), runs behind the thyreohyoideus and perforates the hyothyreoid membrane in company with the superior laryngeal nerve. This vessel, together with the inferior laryngeal artery from the inferior thyreoid (see page 40), supplies the interior of the larynx as well as the neighboring muscles. A long and fairly constant ***cricothyreoid branch*** passes to the cricothyreoideus and anastomoses with its fellow of the opposite side in front of the middle cricothyreoid ligament.

(*c*) The ***sternocleidomastoid branch*** (Fig. 699), a small twig to the muscle of the same name.

(*d*) *Glandular Branches* (Figs. 588 and 695).—The terminal ramification of the artery is upon the thyreoid gland, supplying the isthmus as well as the lateral lobes, and these twigs are frequently given off from two rather distinct branches, an anterior and a posterior.

2. The **lingual artery** (Figs. 544, 695, and 700) arises from the anterior surface of the external carotid above the superior thyreoid, at the level of the superior cornu of the hyoid bone. It is covered by the platysma and the posterior belly of the digastricus and is separated from the hypoglossal nerve by the hyoglossus muscle. It is approximately of the same size as the superior thyreoid artery.

It passes at first upward and inward upon the medial surface of the hyoglossus, and then runs almost horizontally forward upon the under surface of the tongue, giving off the small hyoid and dorsal lingual branches. It now turns rather sharply upward, lying between the hyoglossus and genioglossus, and subdivides into its terminals at the anterior margin of the former muscle. In addition to numerous muscular twigs it gives off:

(*a*) The ***hyoid branch*** (Figs. 695 and 699), usually but a small vessel running to the region of the hyoid bone and neigboring muscles, and anastomosing in front of the body of the bone with its fellow of the opposite side.

(*b*) The ***dorsal lingual branches*** are several small vessels arising from the posterior portion of the artery and passing to the dorsum of the tongue and its mucous membrane, also giving off muscular branches. The most posterior vessels extend to the epiglottis and the palatine tonsil, where they anastomose with the branches of the pharyngeal and ascending palatine arteries.

(*c*) The ***sublingual artery*** (Figs. 544 and 695) is the smaller of the two terminal branches, but seems to be the direct continuation of the lingual itself. It passes beneath the sublingual gland and above the geniohyoideus and mylohyoideus to the floor of the mouth, ramifying in the sublingual gland and the muscles, and gives off branches which perforate the mylohyoideus and anastomose in the submental region with twigs from the submental artery.

(*d*) The ***deep lingual artery*** (Figs. 544 and 695), the larger terminal branch, runs forward and upward to the tip of the tongue between the genioglossus and the longitudinalis inferior, usually pursuing a markedly tortuous course. Numerous small branches are given off to the

muscles and the mucous membrane of the tongue, most of which ascend along the fibers of the genioglossus, and in the region above the lingual frenulum a larger twig anastomoses with the corresponding vessel of the opposite side to form the *ranine arch.*

3. The **ascending pharyngeal artery** (Fig. 693) is a rather small vessel springing from the posterior aspect of the external carotid between the origins of the superior thyreoid and lingual arteries. It occasionally arises from the external maxillary (facial) artery. Together with the internal carotid it ascends along the inner side of the external carotid, resting upon the lateral surface of the pharynx, the upper portion of which it supplies with several pharyngeal branches. These vessels nourish the pharyngeal constrictors, the stylopharyngeus, and the pharyngeal mucous membrane, and terminate in the region of the palatine arches by anastomosing with the ascending palatine and lingual arteries. The upper extremity of the ascending pharyngeal artery extends to the base of the skull, and its two small terminal branches enter the cranial cavity. One of these, the *posterior meningeal artery*, passes through the jugular foramen to the neighboring portions of the dura mater; the other, the *inferior tympanic artery*, accompanies the tympanic nerve through the tympanic canaliculus to the tympanum, where it ramifies upon the promontory.

4. The **external maxillary (facial) artery** (Figs. 539 to 543, 551, 588, 591 to 593, 687, 691, and 692) arises in the carotid fossa from the anterior surface of the external carotid, at the lower margin of the posterior belly of the digastricus and immediately above the origin of the lingual. It passes upward along the inner side of the posterior belly of the digastricus until it reaches the submaxillary region, when it runs almost horizontally forward along the inner surface of the base of the mandible, partly concealed by the submaxillary gland. Near the anterior margin of the insertion of the masseter the vessel passes over the mandible and pursues an oblique and markedly tortuous upward course until it reaches the root of the nose, some portions of its course being superficial, while others are situated between the superficial and deep layers of the facial muscles. The branches of the external maxillary artery may be subdivided into the ascending palatine from the first portion of the artery, the branches arising from the horizontal portion in the submaxillary region, and the facial branches.

(*a*) The *ascending palatine artery* (Figs. 687, 693, and 694) runs upward upon the lateral wall of the pharynx, passing between the styloglossus and stylopharyngeus. It pierces the pharyngeal wall and runs along the pharyngopalatine arch to the soft palate, the isthmus of the fauces, and the nasopharynx, giving off in its course a tonsillar branch for the palatine tonsil. It anastomoses with the ascending pharyngeal artery (from which vessel it occasionally arises), with the descending palatine (see page 29), and with the lingual. This artery not infrequently comes off directly from the external carotid, so that the latter vessel then has ten branches.

In the submaxillary region are given off:

(*b*) The *glandular branches* (Figs. 539 and 687), passing to the submaxillary gland. Similar branches are also given off by the next vessel.

(*c*) The *submental artery* (Figs. 539, 543, 551, 592, 687, and 700), a moderately large vessel situated upon the lower surface of the mylohyoideus, between the anterior belly of the digastricus and the border of the mandible and running forward toward the chin. The artery gives branches to the neighboring parts (gland, muscles, skin), and upon reaching the skin anastomoses

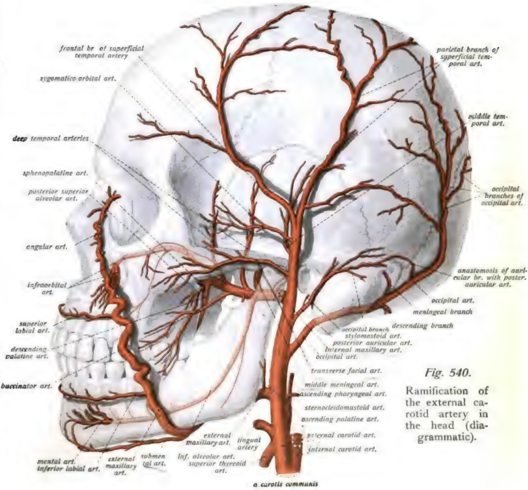


Fig. 540.

Ramification of the external carotid artery in the head (diagrammatic).

with its fellow of the opposite side and with the facial branches of the external maxillary and mental arteries. It is accompanied by the submental vein and the mylohyoid nerve. The facial branches are:

(*d*) The *inferior labial artery* (Figs. 541, 542, 691, and 692), which arises at the level of the lower teeth at the outer margin of the triangularis, passes behind this muscle and runs in the lower lip, either between the muscular fibers or between the musculature and the labial glands at the lower border of the red portion of the lip. It anastomoses in the median line with its fellow of the opposite side, and its course is usually markedly tortuous.

(*e*) The *superior labial artery* (Figs. 540 to 542, 691, and 692) holds the same relation to the upper lip as the preceding vessel does to the lower. It arises from the external maxillary at the point where it becomes superficial between the zygomaticus and the zygomatic head of the quadratus labii superioris. It pursues a tortuous course, gives off a slender twig to the anterior portion of the nasal septum, and anastomoses with the corresponding artery of the opposite side.

(*f*) The terminal portion of the external maxillary is termed the *angular artery* (Figs. 540 to 543, 687, 691, and 692). It runs upward in a tortuous manner behind the ala of the nose and along the lateral surface of the dorsum to the medial angle of the eye, where it anastomoses with the dorsal nasal artery from the ophthalmic. Like the entire facial portion of the external maxillary artery, it gives off in its course numerous small branches to the adjacent musculature and forms anastomoses with neighboring arteries. It does not always extend as far as the medial angle of the eye.

5. The **sternocleidomastoid artery** (Figs. 540 and 700) is a small and fairly constant branch for the muscle of the same name. It arises from the posterior surface of the external carotid at about the level of the origin of the external maxillary. It loops about the hypoglossal nerve and passes downward and forward through the carotid fossa to the anterior margin and internal surface of the sternocleidomastoideus.

6. The **occipital artery** (Figs. 539 to 543, 551, 696 to 700, and 714) is a large vessel which arises from the posterior surface of the external carotid in the retromandibular fossa, above the origins of the two preceding vessels. It passes backward and upward between the posterior belly of the digastricus and the stylohyoideus, toward the space between the transverse process of the atlas and the mastoid process of the temporal bone, in which situation it is covered by the anterior margin of the sternocleidomastoideus. It then turns sharply backward, runs in the occipital groove behind the mastoid process, covered by the longissimus and splenius capitis, becomes markedly tortuous as it passes upward between the semispinalis and trapezius, pierces the insertion of the latter muscle near its outer margin, and runs superficially through the scalp in the occipital region as far as the vertex. In addition to muscular twigs for the sternocleidomastoideus it gives off the following branches:

(*a*) A *mastoid* (*meningeal*) *branch* (Figs. 679, 696, and 714), which passes through the mastoid foramen to the dura mater of the posterior cerebral fossa.

(*b*) *Muscular branches* (Figs. 551 and 696) to the muscles of the neck. One of the largest of these, the *descending branch*, passes downward between the splenius and semispinalis capitis or between the latter muscle and the short muscles of the neck, to anastomose with the vertebral

and deep cervical arteries. These branches are given off from the artery as it lies in the occipital groove; the remaining branches are given off by the superficial terminal portion of the vessel.

(*c*) The ***auricular branch*** (Fig. 697) passes anteriorly toward the posterior surface of the auricle and anastomoses with the occipital branch of the posterior auricular artery.

(*d*) The ***occipital branches*** (Figs. 540 to 542, 591, 696, and 714), the actual terminals, are vessels of considerable size which ramify between the scalp and the galea aponeurotica as they pass through the occipital region to the vertex, where they enter into numerous anastomoses with the ramifications of the parietal branch of the superficial temporal artery. In this situation a small ***parietal*** (***meningeal***) ***branch***, which enters the skull through the parietal foramen, is frequently given off.

7. The **posterior auricular artery** (Figs. 540, 543, and 687) is also given off in the retromandibular fossa, immediately above the occipital, and is a vessel of but moderate size. From its origin beneath the stylohyoideus it runs backward and upward in the groove between the auricle and the mastoid process and there it divides into its terminal branches. With the exception of these terminals it gives off only one important branch.

(*a*) The ***stylomastoid artery*** (Fig. 543) accompanies the facial nerve through the facial canal and makes its exit through the hiatus of the facial canal to anastomose with the superficial petrosal branch of the middle meningeal artery (see page 28). In its course through the facial canal it gives off the following branches: the ***posterior tympanic artery***, passing through the canaliculus chordæ tympani to the tympanum; ***mastoid branches*** to the mastoid cells; and the ***stapedial artery*** to the stapedius, the obturator membrane of the stapes, and to the stapes itself.

The two terminal branches arise by the bifurcation of the posterior auricular behind the ear and are:

(*b*) The ***auricular branch*** (Figs. 697 to 700) to the inner surface of the auricle, also giving off perforating branches to the outer surface.

(*c*) The ***occipital branch***, which passes toward the occiput and anastomoses with the auricular branch of the occipital and with the neighboring twigs of the parietal branch of the superficial temporal artery.

8. The **superficial temporal artery** (Figs. 540 to 543, 591, 592, 687, 691, and 692) is one of the two terminal branches of the external carotid. It arises near the neck of the mandible, in front of the external auditory meatus, by the bifurcation of the trunk of the external carotid. It continues in the upward course of the external carotid and is at first rather deeply placed, being covered by the substance of the parotid gland, but becomes superficial just in front of the tragus and divides immediately above the zygoma into the parietal and frontal branches. Its branches are:

(*a*) ***Parotid branches*** from the commencement of the vessel to the parotid gland.

(*b*) ***Anterior auricular branches*** (Figs. 691 and 692), several small twigs to the external auditory meatus and to the outer surface of the auricle.

(*c*) The ***transverse facial artery*** (Figs, 540 to 543, 691, and 692) runs parallel with the parotid duct, between this structure and the zygoma. It passes over the external surface of the masseter and ramifies in the neighboring muscles and the skin of the cheek, anastomosing freely with other facial arteries (the external maxillary, the buccinator, the infra-orbital).

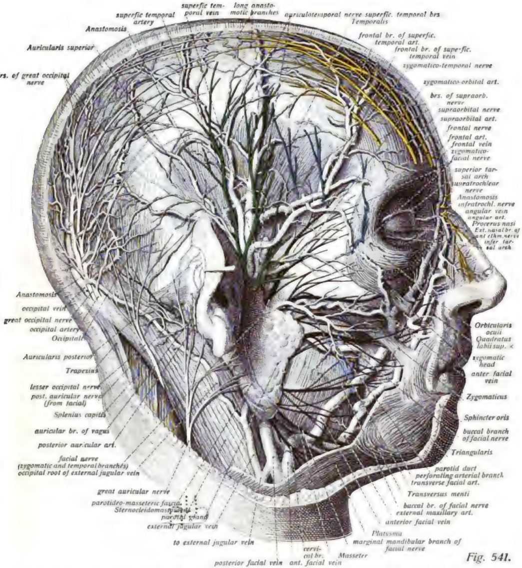


Fig. 541.

Fig. 541 and 542. Superficial nerves and vessels of the head. The facial branches are black, the cervical nerves white, the first branch of trigeminus yellow, the second branch blue and the third branch green. The auricular branch of the vagus is streaked with blue. A portion of the platysma has been removed. The quadratus abii superioris is cut away.

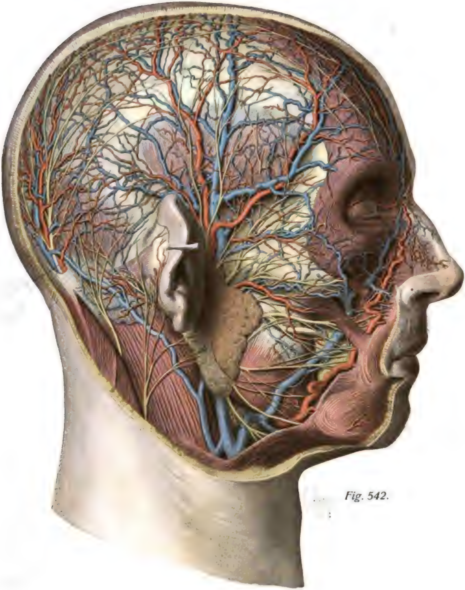


Fig. 542.

(*d*) The *zygomatico-orbital artery* (Figs. 541, 542, 591, 691, and 692) arises near the bifurcation of the superficial temporal, frequently from the frontal branch, and runs above the zygoma to the region of the lateral angle of the orbit, where it ramifies in the neighboring muscles and integument and anastomoses with slender branches of the lachrymal artery.

(*e*) The *middle temporal artery* (Figs. 540, 543, 592, and 687) also arises just before the bifurcation of the parent trunk, pierces the temporal fascia immediately above the zygomatic arch, penetrates the temporal muscle, runs upward in a groove upon the squamous portion of the temporal bone, supplying the temporal muscle, and anastomoses with the deep temporal arteries from the internal maxillary.

(*f*) The *frontal branch* (Figs. 540 to 542, 691, and 692), the anterior terminal of the superficial temporal, pursues a markedly tortuous course immediately beneath the skin, passing forward and upward to the frontal region, where it anastomoses with the ramifications of the frontal branch of the ophthalmic artery.

(*g*) The *parietal branch* (Figs. 540 to 542, 691, and 692), the posterior terminal of the superficial temporal, is likewise tortuous and superficially placed; it passes almost vertically upward and anastomoses freely upon the parietal bone with the neighboring arteries (the frontal branch, the occipital artery, the occipital branch of the posterior auricular artery).

9. The **internal maxillary artery** (Figs. 540, 543, 592, and 687) is the second and larger terminal branch of the external carotid. It is given off at almost a right angle with the trunk of this vessel and passes to the deeper portions of the face, where it pursues a most complicated course, its branches corresponding essentially with the twigs of the second and third divisions of the trigeminal nerve. Immediately after its origin behind the neck of the mandible it passes across the inner surface of this bone, runs forward in a tortuous manner between the muscles of mastication (either between the temporalis and pterygoideus externus or between the two pterygoidei), and after traversing the temporal fossa enters the pterygopalatine fossa. The numerous branches of the vessel, some of which are of great importance, may be subdivided into the following groups according to the region in which they arise: (1) Branches arising at the neck of the mandible—the deep auricular, the anterior tympanic, and the inferior alveolar. (2) Branches given off by the vessel in its passage between the muscles of mastication—the middle meningeal, the masseteric, the deep temporal, the buccinator, and the pterygoid. (3) Shortly before entering the pterygopalatine fossa the vessel gives off the superior posterior alveolar and the infra-orbital arteries and breaks up into its terminal ramifications in the pterygopalatine fossa itself.

(*a*) The *deep auricular artery* (Figs. 543 and 687) is a small twig for the external auditory meatus and the outer surface of the membrana tympani.

(*b*) The *anterior tympanic artery* (Figs. 543 and 687) arises close to the preceding or with it by a common trunk and passes through the petrotympanic fissure to the tympanic cavity. It is the largest of the four small tympanic arteries (see under "Organs of Special Sense") and supplies particularly the anterior portion of the middle ear.

(*c*) The *inferior alveolar* (*dental*) *artery* (Figs. 540, 543, and 592) is considerably larger than the two preceding vessels and passes downward between the ramus of the mandible and the sphenomandibular ligament to the mandibular foramen. Before reaching this orifice it gives off a slender *mylohyoid branch*, which accompanies the nerve of the same name to the mylo-

FIG. 543.—The nerves and vessels of the face. (Fifth layer, the internal maxillary artery.)

The zygomatic arch and the neck and coronoid process of the mandible together with the insertion of the temporalis have been completely removed and the temporalis divided along the temporal artery. The pinna of the external ear has been cut away and the mandibular canal opened up throughout its entire length. ** = Deep auricular and anterior tympanic arteries. * = Deep auricular branches of auriculotemporal nerve.

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hyoid muscle. Within the mandibular canal the artery gives branches to the individual dental alveoli and roots of the teeth, and also gives off a terminal branch, the *mental artery*, which passes through the mental foramen to supply the muscles and integument of the chin and to anastomose with the submental and inferior labial arteries.

(*d*) The *middle meningeal artery* (Figs. 543, 679, 682, and 687) is the largest branch of the parent trunk; it arises obliquely opposite to the preceding vessels and passes upward upon the internal surface of the pterygoideus internus to the foramen spinosum, giving off in its course slender twigs to the neighboring muscles (the pterygoideus externus and the palatal muscles). Before entering the foramen spinosum it gives off a small *accessory meningeal branch*, which passes through the foramen ovale to the semilunar ganglion of the trigeminal nerve. In the cranial cavity the artery gives off small twigs to the petrous portion of the temporal bone. The *superficial petrosal branch* (Fig. 679) passes with the nerve of the same name to the hiatus of the facial canal and anastomoses with the stylomastoid branch of the posterior auricular artery; it supplies the tensor tympani and gives off the *superior tympanic artery* (Fig. 679) to the tympanum, although this vessel may arise independently from the middle meningeal itself. This superior tympanic artery runs in the groove for the lesser superficial petrosal nerve, reaches the promontory in the tympanum together with this nerve by passing through the aperture of the superior tympanic canaliculus, and is distributed particularly to the epitympanic recess.

The trunk of the middle meningeal artery now immediately divides into a larger *anterior* and a somewhat smaller *posterior branch*. The ramifications of these vessels are situated in the dura mater, close to the bone in the sulci arteriosi (occasionally even within the bone in some portion of their course), and reach the cranial vault by passing upward upon the internal surface of the lateral wall of the cranium. The anterior branch passes over the greater wing of the sphenoid and the anterior portion of the parietal bone and extends as far as the frontal bone; the posterior branch runs across the squamous portion of the temporal bone to the occipital bone.

(*e*) The *masseteric artery* (Figs. 591 and 592) is a rather small vessel which, together with the nerve of the same name, runs through the mandibular notch to the internal surface of the masseter. It is not the only vessel for this muscle, its external surface being supplied by branches of the transverse facial artery. Instead of arising independently from the internal maxillary the masseteric artery frequently comes from the following vessel.

(*f*) The *posterior deep temporal artery* (Figs. 543 and 687) passes upward to the temporal muscle, which it supplies in association with the following vessel and the middle temporal. It runs posterior and approximately parallel to the sphenosquamous suture, and is situated in the muscle itself and not upon the bone.

(*g*) The *anterior deep temporal artery* (Figs. 543 and 687) runs in front of and parallel to the preceding vessel and is in direct contact with the temporal surface of the greater wing of

the sphenoid bone. It also supplies the temporalis and usually gives off a small branch through the zygomaticotemporal foramen in the zygomatic (malar) bone, which, together with the zygomaticofacial nerve, passes to the integument of the cheek and through the zygomatico-orbital foramen to the orbit, where it may take part in supplying the lachrymal gland by anastomosing with the lachrymal artery.

(*h*) The *pterygoid branches* (Fig. 543) are a number of variable twigs for the muscles of the same name. They may originate either directly from the internal maxillary or from one of its branches (the buccinator or the deep temporals).

(*i*) The *buccinator artery* (Figs. 540, 543, 691, and 692) usually arises between the two deep temporal arteries, but from the opposite side of the trunk, since it passes downward. Together with the nerve of the same name it runs between the masseter and the buccinator, curves anteriorly, ramifies in the buccinator muscle which it pierces, and is also distributed to the mucous membrane of the cheek and the neighboring facial muscles. It anastomoses freely with the branches of the external maxillary, transverse facial, and other arteries.

(*j*) The *posterior superior alveolar (dental) artery* (Fig. 543) arises from the internal maxillary, as this vessel rapidly diminishes in caliber before entering the pterygopalatine fossa, and divides into several branches which enter the alveolar foramina of the maxillary tuberosity, run through bony canals to the roots of the upper molar and premolar teeth, and also supply the neighboring gum and the mucous membrane of the maxillary sinus.

(*k*) The *infra-orbital artery* (Figs. 540, 543, 591, 592, 691, and 692) is a vessel of fair size which runs through the infra-orbital canal of the superior maxilla (see Vol. I, page 66). The artery enters the orbit through the inferior orbital fissure, runs along the orbital floor in the infra-orbital sulcus, passes through the infra-orbital canal, and reaches the deeper portions of the face through the infra-orbital foramen. In the orbit it gives off branches to the inferior oblique and rectus muscles and to the orbital contents in general; in the infra-orbital canal it gives origin to the *anterior superior alveolar (dental) arteries*, which run, together with the nerves of the same name, in the wall of the maxillary sinus to the upper canine and incisor teeth. The terminal ramification of the artery takes place in front of the infra-orbital foramen in the overlying and adjacent muscles, where it anastomoses with the neighboring arteries (the superior alveolar, the angular, and others).

The two terminal branches of the internal maxillary artery arising in the pterygopalatine fossa are:

(*l*) The *descending palatine artery* (Fig. 685) which gives off the small *(Vidian) artery of the pterygoid canal*, passing through the pterygoid canal with the nerve of the same name to reach the upper portion of the pharynx. As it passes downward through the pterygopalatine canal the descending palatine artery subdivides into two branches corresponding to the bifurcation of the canal. The larger anterior one is the *greater palatine artery*, which passes to the mucous membrane of the hard palate and to the gum and anastomoses with branches of the nasal arteries through the incisive canal. The smaller posterior ones are the *lesser palatine arteries*, which pass through the posterior palatine foramina to the soft palate, the palatine arch, and the palatine tonsil, and anastomose with the branches of the ascending pharyngeal and particularly with the ascending palatine artery.

FIG. 544.—The nerves and arteries of the nasal septum and of the tongue.

* = Divided posterior pharyngeal wall. ** = Sphenoidal sinus.

FIG. 545.—The nerves and arteries of the outer nasal wall and of the palate.

The tongue has been drawn out, all of the nasal septum except its lower portion removed, and the mucous membrane of the faucial isthmus divided along the glossopharyngeal nerve and the ascending palatine artery. ** = Sphenoidal sinus. * = Divided branches to nasal septum. *** = Anastomosis between nasopalatine and anterior palatine nerves. * † = Mucous membrane of hard palate.

FIG. 546.—The nerves and arteries of the orbit. (Third layer.)

Dissection as in Fig. 683. The rectus superior, obliquus superior, and levator palpebræ superioris have been divided and the rectus lateralis drawn slightly to one side. * = Branch of oculomotor nerve to rectus medialis.

FIG. 547.—The nerves and arteries of the orbit. (Fourth layer.)

Dissection as in Fig. 546. The rectus lateralis, the optic nerve, and the anterior portion of the ophthalmic artery have been divided, and the eyeball with the stump of the optic nerve rolled forward to show the ramification of the lower branch of the oculomotor nerve. The canals for the anterior and posterior ethmoidal arteries and veins have also been opened. ** = Branch of oculomotor nerve to rectus inferior; *** = to obliquus inferior.

(*m*) The ***sphenopalatine artery*** (Figs. 544, 545, and 685), the second of the terminal branches of the internal maxillary, is the largest artery of the nasal cavity. It passes through the sphenopalatine foramen to the nasal cavity, where it ramifies upon the posterior portions of the outer nasal wall and of the nasal septum. Its branches are termed the ***posterior external nasal arteries*** and the ***posterior artery of the nasal septum.*** The latter vessel accompanies the nasopalatine nerve through the incisive canal to meet the anterior palatine artery. Slender twigs are given off to the frontal and maxillary sinuses and a branch passes through the pharyngeal canal (see Vol. I, page 49) to the pharynx.

THE INTERNAL CAROTID ARTERY.

The *internal carotid artery* (Figs. 543, 546 to 549, 687, and 693) continues upward approximately in the same direction as the common carotid. It is situated deeply in the retromandibular fossa near the lateral wall of the pharynx, internal and posterior to the external carotid artery from which it is separated by the styloglossus and stylopharyngeus. The artery is accompanied by the internal jugular vein, which is placed to its outer side and somewhat posterior, and in its immediate neighborhood are the sympathetic trunk with its superior cervical ganglion, the vagus nerve with its nodular ganglion (posterior or postero-external), the glossopharyngeal nerve (anterior), and the hypoglossal nerve (external). The course of the artery is fairly straight and it gives off no branches until it reaches the base of the skull. Shortly before entering the carotid canal it makes an S-shaped curve, then runs through the canal surrounded by a sympathetic and a venous plexus, leaves the canal through the internal carotid foramen, and passes upward and forward between the two layers of the dura mater in the carotid sulcus of the sphenoid bone and enclosed within the cavernous sinus (see page 86) until it reaches the anterior clinoid process. In this situation the artery curves upward and slightly backward, the convexity of the curve being anterior, to pierce the dura mater and reach the brain.

The artery is peculiar in that during its course through the petrous portion of the temporal bone it gives off only a very small twig to the tympanum, and during its course beneath the dura mater it likewise gives off only insignificant branches to the surrounding structures (to the semi-

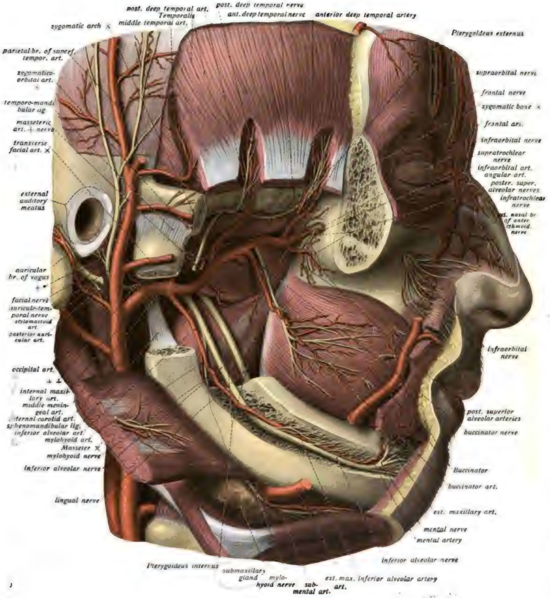
post. deep temporal art.
Temporalis
middle temporal art.
zygomatic arch ×
post. deep temporal nerve
ant. deep temporal nerve
anterior deep temporal artery
Pterygoideus externus
parietal br. of superf. tempor. art.
zygomatico-orbital art.
temporo-mandibular lig.
masseteric art. + nerve
transverse facial art. ×
external auditory meatus
auricular br. of vagus
+ •
facial nerve
auriculo-temporal nerve
stylomastoid art.
posterior auricular art.
occipital art.
+ ⊥
internal maxillary art.
middle meningeal art.
ternal carotid art.
sphenomandibular lig.
inferior alveolar art.
mylohyoid art.
Masseter ×
mylohyoid nerve
inferior alveolar nerve
lingual nerve
supraorbital nerve
frontal nerve
zygomatic bone ×
frontal art.
infraorbital nerve
supratrochlear nerve
infraorbital art.
angular art.
poster. super. alveolar nerves
infratrochlear nerve
t. nasal br of anter. ethmoid. nerve
infraorbital nerve
post. superior alveolar arteries
buccinator nerve
Buccinator
buccinator art.
ext. maxillary art.
mental nerve
mental artery
inferior alveolar nerve
Pterygoideus internus
submaxillary gland
mylohyoid nerve
submental art.
ext. max. art.
inferior alveolar artery

Fig. 543.

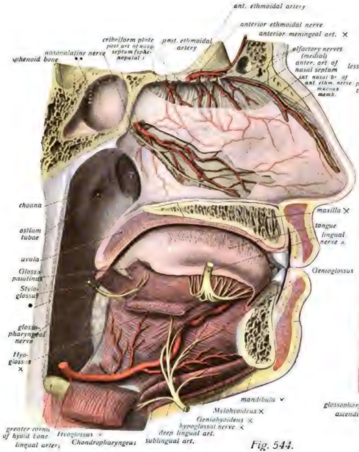

Fig. 544.

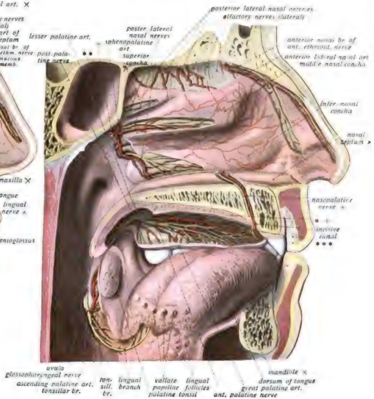

Fig. 545.

lunar ganglion of the trigeminal nerve, to the hypophysis, etc.). The first branch of considerable size is the ophthalmic artery; all other branches go to the brain.

The branches of the internal carotid artery are:

1. The *caroticotympanic branch*, which arises from the vessel as it passes through the petrous portion of the temporal bone, and runs through the caroticotympanic canal to the tympanum.

2. The *ophthalmic artery* (Figs. 546, 547, 682, and 683) arises from the convexity of the last curve in the course of the internal carotid, at the inner side of the anterior clinoid process, and passes together with the optic nerve through the optic foramen into the orbit. The artery is at first internal to the optic nerve, at the optic foramen it is inferior, and upon leaving the foramen it is external. It next crosses over the nerve obliquely toward the inner wall of the orbit, where it pursues a tortuous course along the superior oblique muscle as far as the trochlea, beneath which it divides into its terminals. Its branches are:

(*a*) The *lachrymal artery* (Figs. 546 and 547), which arises beneath the levator palpebræ superioris and the rectus superior, and runs forward to the lachrymal gland between these muscles and the rectus lateralis, near the outer wall of the orbit. It gives off small twigs to the adjacent muscles and supplies the lachrymal gland and the external portion of the conjunctiva. Its terminal branches are the lateral *palpebral arteries* for the outer halves of both lids. It anastomoses with the branches of the anterior deep temporal artery which enter the orbit, and with the zygomatico-orbital artery (see page 27).

(*b*) The *muscular branches* (Figs. 546, 547, 682, 683, and 743) supply the numerous muscles of the orbit, some of them occasionally arising from branches of the artery instead of from the vessel itself. They give off the *anterior ciliary arteries* to the eyeball.*

(*c*) The *posterior ciliary arteries* (Figs. 547, 682, 731, 743, and 744) are subdivided, according to their course in the eyeball, into the *long* and *short posterior ciliary arteries*, the long being two in number and the short four or five small twigs. They arise from the ophthalmic itself or from one of its larger branches, and pierce the sclerotic in the posterior portion of the eyeball. (For further details see under "Organs of Special Sense.") Their origins, like those of the following vessels, are situated in the most posterior portion of the orbital cavity, where the ophthalmic artery passes transversely above the optic nerve.

(*d*) The *central artery of the retina* (Figs. 742 and 745) arises together with the preceding vessels and penetrates the optic nerve about 1 cm. behind the eyeball, by piercing the outer and lower portion of the sheath of the nerve. It runs in the axis of the nerve to the retina. (For further details see under "Organs of Special Sense.")

(*e*) The *anterior ciliary arteries* (Figs. 731, 743, and 744) are very slender twigs, seven to eight in number, which usually originate from the muscular branches and pass to the eyeball with the tendons of the straight ocular muscles. (For further details see section on "Organs of Special Sense.")

(*f*) The *supra-orbital artery* (Figs. 546, 682, and 683) pursues a rather tortuous course and, in company with the nerve of the same name, passes between the peri-orbita and the levator palpebræ superioris to the supra-orbital foramen, giving off small branches to the surrounding

* The conjunctival and episcleral arteries are also derived from the muscular branches. (For details see under "Organs of Special Sense.")

FIG. 548.—The arteries of the base of the brain.

Upon the right side, the tip of the temporal lobe, the cerebellar hemisphere, and the optic nerve have been removed.

FIG. 549.—The arteries of the mesial surface of the cerebrum and of the surface of the cerebellum.

The left cerebral hemisphere has been removed by a median section of the corpus callosum and by an oblique section of the cerebral peduncle.

tissues and to the musculature and integument of the forehead. It anastomoses with the frontal and zygomatico-orbital arteries and with the frontal branch of the superficial temporal artery.

(g) The *posterior ethmoidal artery* (Figs. 546 and 547), an insignificant vessel, passes through the foramen of the same name and ramifies in the ethmoid cells and partly also in the contiguous portion of the nasal cavity.

(h) The *anterior ethmoidal artery* (Figs. 546 and 547), a larger vessel than the preceding, enters the cranial cavity through the anterior ethmoidal foramen, lies upon the upper surface of the cribriform plate of the ethmoid bone, where it gives off the *anterior meningeal artery* to the dura mater of the anterior cerebral fossa, and passes through the cribriform plate into the nasal cavity, the anterior part of which it supplies by dividing into the *anterior lateral nasal artery* for the lateral wall and the *anterior artery of the septum.*

After giving off these branches the trunk of the ophthalmic artery is much reduced in size and, upon reaching the anterior medial portion of the orbit, divides into the following three terminals:

(i) The *medial palpebral artery* or *arteries* (Figs. 691 and 692) run to the medial halves of the eyelid, forming the *superior* and *inferior tarsal arches* with the lateral palpebral arteries.

(j) The *frontal artery* (Figs. 541, 542, 546, 691, and 692) continues in the direction of the ophthalmic stem and is consequently to be regarded as the actual terminal branch. Accompanied by the nerve of the same name it runs through the frontal notch and is reflected over the upper margin of the orbit to the musculature and integument of the forehead, where it anatomoses with the supra-orbital artery and with the frontal branch of the superficial temporal.

(k) The *dorsal artery of the nose* (Figs. 546, 691, and 692) pierces the orbicularis oculi above the medial palpebral ligament and ramifies in the skin and muscles in the vicinity of the medial angle of the orbit. In this situation it anastomoses with the angular artery, the terminal branch of the external maxillary.

THE CEREBRAL BRANCHES OF THE INTERNAL CAROTID ARTERY.

Immediately after piercing the dura mater at the base of the brain the internal carotid artery divides into four branches:

3. The *posterior communicating artery* (Figs. 548 and 549), usually quite small in size,* runs past the tuber cinereum and the mammillary bodies to the posterior cerebral artery, the terminal branch of the vertebral. It gives off branches to the neighboring portions of the base of the brain and forms the connection between the two principal cerebral arteries.

4. The *chorioid artery* (Figs. 548, 636, and 638) is a small twig which passes along the optic

* The posterior communicating artery is occasionally large upon one side, especially if the vertebral artery of the same side be small.

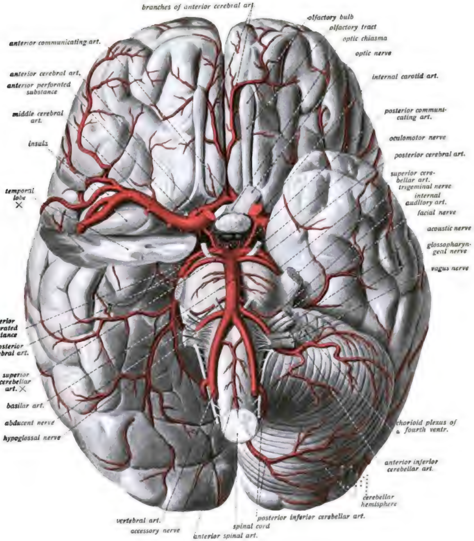
branches of anterior cerebral art.
olfactory bulb
olfactory tract
optic chiasma
optic nerve
anterior communicating art.
anterior cerebral art.
anterior perforated substance
internal carotid art.
middle cerebral art.
posterior communicating art.
insula
oculomotor nerve
posterior cerebral art.
superior cerebellar art.
trigeminal nerve
temporal lobe ×
internal auditory art.
facial nerve
acoustic nerve
glossopharyngeal nerve
vagus nerve
posterior perforated substance
posterior cerebral art.
superior cerebellar art. ×
basilar art.
abducent nerve
hypoglossal nerve
chorioid plexus of fourth ventr.
anterior inferior cerebellar art.
cerebellar hemisphere
vertebral art.
accessory nerve
posterior inferior cerebellar art.
spinal cord
anterior spinal art.

Fig. 548.

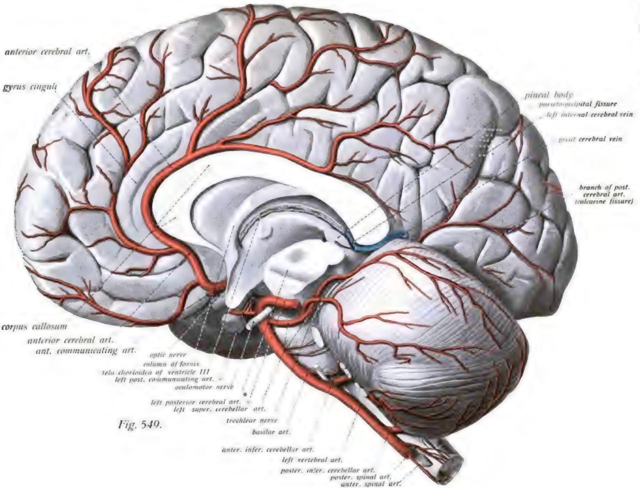
anterior cerebral art.
gyrus cinguli
corpus callosum
anterior cerebral art.
ant. communicating art.
optic nerve
column of fornix
tela chorioidea of ventricle III
left post. communicating art.
oculomotor nerve
left posterior cerebral art.
left super. cerebellar art.
trochlear nerve
basilar art.
anter. infer. cerebellar art.
left vertebral art.
poster. infer. cerebellar art.
poster. spinal art.
anter. spinal art.
pineal body
parieto-occipital fissure
left internal cerebral vein
great cerebral vein
branch of post.
cerebral art.
(calcarine fissure)

Fig. 549.

tract to the lateral surface of the crus cerebri, in which situation it enters the inferior horn of the lateral ventricle to supply the chorioid plexus.

5. The *anterior cerebral artery* (Figs. 548 and 549) is considerably larger than the two preceding vessels, but smaller than the middle cerebral, and is one of the two terminals of the internal carotid artery. The arteries of the two sides are connected with each other at the base of the brain in front of the optic chiasm and lamina terminalis by the *anterior communicating artery*, which, though of fair caliber, is but a few millimeters in length. The hypophyseal region of the base of the brain is consequently surrounded by a circular anastomosis of the four vessels supplying the brain, and this anastomotic ring is designated as the *arterial circle of Willis.* The carotids of the two sides are connected with each other by means of the anterior communicating artery, while upon either side the internal carotid is connected by the posterior communicating branch with the terminal branch of the basilar artery of the same side (see page 36).

Before the anterior cerebral artery gives off the anterior communicating artery it sends small twigs into the foramina of the anterior perforated substance. After the origin of the communicating branch the trunk of the vessel sinks into the longitudinal cerebral fissure, runs upon the upper surface of the corpus callosum beside or above the artery of the opposite side, and ramifies chiefly upon the medial surface of the cerebral hemisphere.

6. The *middle cerebral artery* (Figs. 548 and 549), the second terminal of the internal carotid, runs laterally to enter the lateral (Sylvian) fissure, in which situation it gives off its branches. The main ramifications are to the convolutions of the temporal, occipital, and parietal lobes, which surround the lateral fissure, and to the convolutions of the insula. Shortly after its origin the artery sends branches through the posterior perforated substance to the corpus striatum.

THE SUBCLAVIAN ARTERY.

The *subclavian artery* (Figs. 538, 539, 550, 551, 699, and 700) supplies the entire upper extremity including the region of the shoulder, the greater portion of the cervical and nuchal regions, the upper and middle portions of the thoracic wall, some of the cervical viscera, the posterior portion of the brain, and the upper portion of the spinal cord. There is scarcely another artery in the body which has so large an area of distribution.

Its origin differs upon the two sides, inasmuch as the right artery comes from the innominate, while the left arises directly from the aortic arch. The left subclavian artery is consequently longer than the right and runs for a short distance through the thoracic cavity behind the left innominate vein. Its origin from the aortic arch is immediately lateral to that of the left common carotid artery, and from this point it runs behind the outer portion of the sterno-clavicular joint and reaches the neck by passing through the superior thoracic aperture. The further relations and course of the vessels are the same upon both sides.

The artery is known as the subclavian until it passes behind the clavicle and the subclavius muscle, when it is called the *axillary artery;* upon leaving the axilla and passing to the upper arm the vessei again changes its name and is designated as the *brachial artery.* It does not divide into its termmal branches until it reaches the bend of the elbow, and the subclavian, axillary, and brachial arteries consequently form a continuous stem, the differentiation into three parts being purely regional.

After passing through the superior thoracic aperture the subclavian artery passes upward and outward over the pleural cupola, resting in the subclavian groove of the lung (during deep inspiration). In the neck it forms a marked curve, the convexity of which is directed upward, and passes over the first rib in the subclavian groove. At the same time it passes through the scalene interspace and, together with the brachial plexus, is situated between the scalenus anterior and the scalenus medius, the scalenus anterior separating it from the subclavian vein, which is in front and somewhat medial. In addition to the scalenus anterior the artery is also covered by the internal jugular vein, the intermediate tendon of the omohyoideus, and the sternocleidomastoideus. To the outer side of the scalenus anterior the subclavian artery is rather superficially placed in the supraclavicular fossa, although it is not immediately beneath the skin and platysma, but is covered also by the superficial layer of the cervical fascia, by fatty tissue, and by lymphatic glands, and in this situation it is also in relation above with the brachial plexus, which accompanied it in its passage through the scalene interspace. The vessel then passes over the first rib, lateral to the subclavian vein, medial to the brachial plexus, and behind the middle of the clavicle, to become the axillary artery.

The branches of the subclavian artery show an inclination to arise in groups from short common vessels, which are designated as trunks. There are usually two such vessels—the *costocervical trunk* and the larger *thyreocervical trunk*. The origins of the branches are, however, very variable and one artery frequently replaces another either wholly or in part.* Almost all the branches arise from a very circumscribed portion of the artery, since no large vessel arises within the thorax and the terminal portion of the artery gives off only the transverse cervical artery. All the remaining branches arise from that portion of the subclavian which is situated between its exit from the superior thoracic aperture and its entrance into the scalene interspace.

The branches of the subclavian artery are:

1. The **vertebral artery** (Figs. 539, 548 to 551, and 696), a large and important vessel which, like the internal carotid, passes to the brain and supplies its posterior portion. It arises from the upper surface of the commencement of the subclavian arch,† and passes almost vertically upward to the foramen transversarium of the sixth cervical vertebra, being situated in front of the outer margin of the longus colli, at first behind the common carotid and subsequently behind the inferior thyreoid artery. It then continues its vertical course upward by passing through the foramina transversaria of the fifth to the second cervical vertebræ, lying in front of the emerging spinal nerves. It then passes in a curve to the foramen transversarium of the atlas,‡ through which it passes, and then runs almost horizontally in the vertebral groove upon the posterior arch of the atlas to the foramen magnum, lying upon the posterior atlanto-occipital membrane in a triangle formed by the obliquus capitis superior, the obliquus capitis inferior,

* See footnote on page 41.

† In addition to the occasional direct origin of the vertebral artery from the aortic arch (see page 41), the following anomalies may also occur: The artery of one side is frequently much smaller than its fellow of the opposite side; it may occasionally be double; it sometimes passes partly or almost wholly outside of the canal in the transverse processes of the cervical vertebræ.

‡ Since the transverse process of the atlas extends much beyond that of the axis, the artery must run upward and markedly outward.

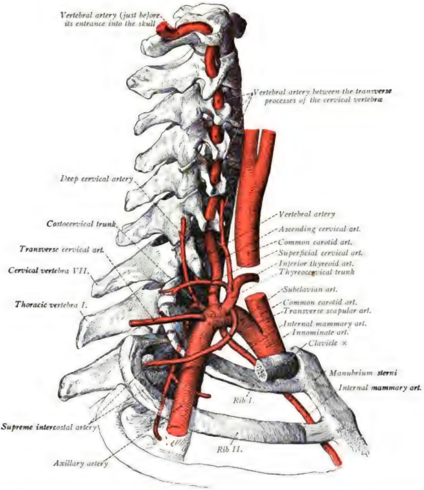

FIG. 550.—The branches of the subclavian artery and the course of the vertebral artery in the neck (schematic).

and the rectus capitis posterior major muscles. Above the posterior arch of the atlas the artery pierces the posterior atlanto-occipital membrane and enters the cranial cavity through the foramen magnum.

In the cranial cavity the vertebral artery is situated at first upon the lateral surface and

FIG. 551.—The nerves and arteries of the deep layers of the neck and of the axilla. (Sixth layer of neck, deeper layer of the axilla, see also Fig. 552.)

The greater portions of the infrahyoid muscles and of the common carotid artery have been removed; the clavicle has been disarticulated at the sternoclavicular joint and sawn through at about its middle. The pectoralis major and minor have been divided and the deltoid incised along the deltoid branch of the thoraco-acromial artery. * = Accessory sympathetic ganglion.

FIG. 552.—The deeper layer of the vessels and nerves of the axilla.

The pectoralis major has been divided (as has the sternocleidomastoideus in the neck) and reflected to either side.

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then in front of the medulla oblongata. At the junction of the medulla with the pons the arteries of the two sides unite at an acute angle to form the unpaired *basilar artery.*

The chief ramification of the vertebral artery takes place in the cranial cavity. In the neck it gives off only a few unimportant branches; these are:

(*a*) *Spinal branches*, which pass through the intervertebral foramina of the cervical column to the membranes of the spinal cord and to the spinal cord itself.

(*b*) *Muscular branches* (Fig. 696), several small vessels which pass to the nuchal muscles and anastomose with the occipital, the deep cervical, and the ascending cervical arteries.

(*c*) A *meningeal branch* (Fig. 679) passes through the great occipital foramen to the neighboring portions of the dura mater.

In the cranial cavity the artery gives off:

(*d*) The *posterior spinal artery* (Fig. 549), a very slender twig arising at the level of the foramen magnum and uniting upon the posterior aspect of the spinal cord with its fellow of the opposite side to form an elongated network, which is continued throughout the thoracic and lumbar portions of the spinal cord by anastomoses with the spinal branches of other arteries (see below).

(*e*) The *anterior spinal artery* (Figs. 548 and 549) is larger than the preceding vessel and, after a short course, joins with its fellow of the opposite side to form a single artery, which runs downward in a tortuous manner in front of the anterior median fissure of the spinal cord and is continued to the inferior extremity of the cord by the spinal branches of the vertebral, intercostal, and lumbar arteries. Some of its branches penetrate the spinal cord through the anterior median fissure, while others form transverse anastomoses in the pia mater with the branches of the posterior spinal arteries.

Before the vertebral arteries unite to form the basilar, each vessel gives off one of the cerebellar arteries.

(*f*) The *posterior inferior cerebellar artery* (Figs. 548 and 549) arises at the lateral surface of the medulla oblongata, frequently below the preceding vessel, and is much larger than either the anterior or the posterior spinal branches. It passes laterally, backward, and downward to the under surface of the posterior half of the cerebellar hemisphere and to the lower portion of the vermis of the cerebellum; it also gives off slender twigs to the medulla oblongata.

The Basilar Artery.—The basilar artery (Figs. 548 and 549) is formed by the junction at an acute angle of the two vertebral arteries, at the dividing-line between the medulla and the pons. It is a large single vessel which runs over the clivus, and along the antero-inferior surface

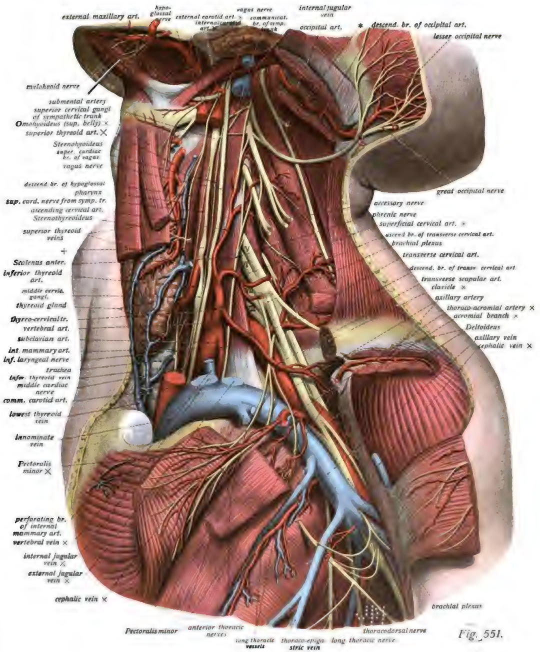
external maxillary art.
hypo-glossal nerve
external carotid art ×
internal carotid art. ×
vagus nerve
communicat. br. of symp. trunk
internal jugular vein
occipital art.
* descend. br. of occipital art.
lesser occipital nerve
mylohyoid nerve
submental artery
superior cervical gangl of sympathetic trunk
Omohyoideus (sup. belly) ×
superior thyreoid art. ×
Sternohyoideus
super. cardiac br. of vagus
vagus nerve
descend br. of hypoglossal
pharynx
sup. card. nerve from symp. tr.
ascending cervical art.
Sternothyreoideus
superior thyreoid veins
+
Scalenus anter.
inferior thyreoid art.
middle cervic. gangl.
thyreoid gland
thyreo-cervical tr.
vertebral art.
subclavian art.
int. mammary art.
inf. laryngeal nerve
trachea
infer. thyreoid vein
middle cardiac nerve
comm. carotid art.
lowest thyreoid vein
innominate vein
Pectoralis minor ×
perforating br. of internal mammary art.
vertebral vein ×
internal jugular vein ×
external jugular vein ×
cephalic vein ×
great occipital nerve
accessory nerve
phrenic nerve
superficial cervical art. ×
ascend br. of transverse cervical art.
brachial plexus
transverse cervical art.
descend. br. of transv. cervical art.
transverse scapular art.
clavicle ×
axillary artery
thoraco-acromial artery ×
acromial branch ×
Deltoideus
axillary vein
cephalic vein ×
brachial plexus
Pectoralis minor
anterior thoracic nerves
long thoracic vessels
thoraco-epigastric vein
long thoracic nerve
thoracodorsal nerve

Fig. 551.

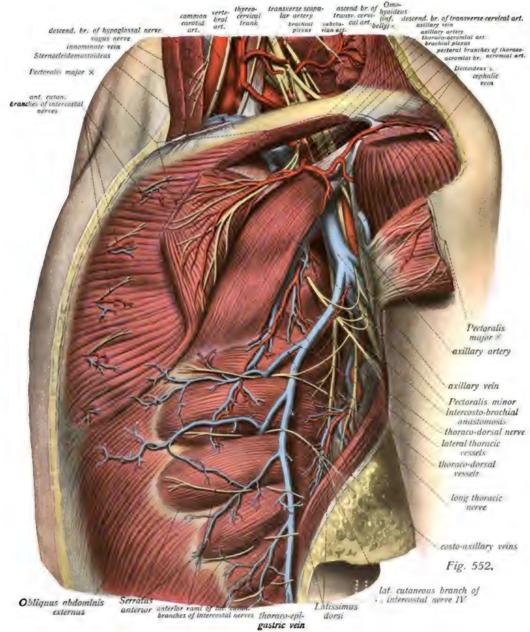
common carotid art.
verte-bral art.
thyreo-cervical trunk
transverse scapular artery
brachial plexus
subclavian art.
ascend br. of transv. cervical art.
Omohyoideus (inf. belly)
descend. br. of transverse cervical art.
axillary vein
axillary artery
thoraco-acromial art
brachial plexus
pectoral branches of thoraco-acromial art.
acromial br.
Deltoideus
cephalic vein
descend. br. of hypoglossal nerve
vagus nerve
innominate vein
Sternocleidomastoideus
Pectoralis major ×
ant. cutan. branches of intercostal nerves
Pectoralis major
axillary artery
axillary vein
Pectoralis minor
intercosto-brachial anastomosis
thoraco-dorsal nerve
lateral thoracic vessels
thoraco-dorsal vessels
long thoracic nerve
costo-axillary veins
lat. cutaneous branch of intercostal nerve IV
Obliquus abdominis externus
Serratus anterior
anterior rami of lat. cutan. branches of intercostal nerves
thoraco-epigastric vein
Latissimus dorsi

Fig. 552.

of the pons, being situated exactly in the median line and producing the basilar pontine sulcus. Upon reaching the anterior superior border of the pons it breaks up into two terminals in the interpeduncular fossa. All of its branches are paired. They are:

1. The *pontine branches* (Fig. 548), small direct twigs to the pons.

2. The *anterior inferior cerebellar artery* (Figs. 548 and 549) passes transversely across the posterior portion of the pons, usually behind the abducent nerve, and between the acoustico-facial and vago-glossopharyngeal trunks, and ramifies upon the anterior superior portion of the under surface of the cerebellar hemisphere.

3. The *internal auditory artery* (Fig. 548) is a slender vessel which runs parallel with the preceding and accompanies the acoustic nerve through the internal auditory meatus to the internal ear. It anastomoses with the stylomastoid branch of the posterior auricular artery. (For further details see "The Ear.")

4. The *superior cerebellar artery* (Figs. 548 and 549) runs almost transversely across the anterior portion of the pons, and then turns upward and backward to ramify upon the upper surface of the cerebellar hemisphere and on the superior vermis. Small twigs pass to the corpora quadrigemina, the pineal body, and the tela chorioidea of the third ventricle.

5. The *posterior cerebral artery* (Figs. 548 and 549), the paired terminal branch of the basilar, is separated at its origin from the preceding vessel by the oculomotor nerve. It first runs outward and somewhat forward, then bends backward and upward around the crus cerebri until it comes to lie above the tentorium cerebelli, and ramifies chiefly upon the concave inferior surface of the temporal and occipital lobes, its branches extending toward the convexity of the hemisphere.

Shortly after its origin it is joined by the posterior communicating artery from the internal carotid (see page 32), the lateral portion of the arterial circle of Willis being thus completed. In addition to the branches to the cerebral hemisphere, it gives off slender twigs to the interpeduncular fossa, the mammillary bodies, the cerebral peduncle, the posterior extremity of the thalamus, the superior colliculi, the splenium of the corpus callosum, the inferior horn of the lateral ventricle, and the chorioid plexus of this and of the third ventricle.

2. The **internal mammary artery** (Figs. 539, 550, and 553) arises from the subclavian almost exactly opposite the vertebral and from the concavity of the beginning of the subclavian arch. It passes over the anterior surface of the pleural cupola, behind the subclavian vein, to the posterior surface of the sternoclavicular joint and of the muscles arising in this situation (the sternohyoideus and the sternothyreoideus). It then passes almost directly downward upon the posterior surface of the costal cartilages, about 1 cm. from the sternal margin, being in relation posteriorly with the costal pleura and the transversus thoracis, and at the level of the fifth or sixth costal cartilage divides into its terminals. The artery sends numerous branches to the anterior thoracic and abdominal walls, to the thoracic viscera, to the pericardium, and to the diaphragm, all the branches being given off after the artery enters the superior thoracic aperture. The branches are:

(*a*) The *anterior mediastinal arteries*, small twigs which pass to the lymphatic nodes situated in the anterior mediastinum, and to the large vessels.

(*b*) The *thymic arteries*, small branches to the thymus gland.

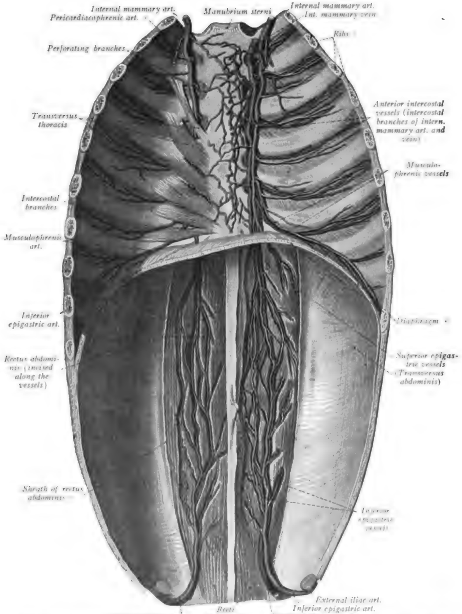

FIG. 553.—The course and branches of the internal mammary artery. The posterior thoracic and abdominal walls have been removed by a frontal section. The anastomosing branches of the superior and inferior epigastric arteries have been exposed by incising the rectus abdominis.

(*c*) The *bronchial branches* go to the bifurcation of the trachea and follow the bronchus to the pulmonary hilus, where they anastomose with the bronchial arteries from the aorta.

(*d*) The *pericardiacophrenic artery* (*comes nervi phrenici*) (Fig. 701) is a very long slender vessel which, together with the phrenic nerve, passes downward upon the lateral surface of the pericardium, covered by the pericardiac pleura, and ramifies in the pericardium and also in the diaphragm.

(*e*) The *perforating branches* (Fig. 593), seven to eight in number, pierce the internal intercostal muscles in the anterior portions of the intercostal spaces and give off cutaneous branches to the integument of the chest and muscular branches to the thoracic musculature (pectoralis major). The third, fourth, and fifth perforating branches in the female give off *mammary branches* to the mammary gland; the first is frequently of considerable size and makes its appearance between the two heads of the sternocleidomastoideus. The perforating branches also give off small *sternal branches* to the posterior surface of the sternum.

(*f*) The *anterior intercostal arteries* (Fig. 553) run in the anterior portions of the upper five or six intercostal spaces and anastomose with the anterior extremities of the posterior intercostal arteries from the aorta.

(*g*) The *musculophrenic artery* (Fig. 553), one of the terminal branches of the internal mammary, passes along the upper margin of the costal origin of the diaphragm and upon the inner surface of the costal arch, from the sixth to the tenth costal cartilages. It gives off the anterior intercostal branches for the sixth or the seventh to the tenth intercostal spaces, and sends numerous muscular branches to the costal portion of the diaphragm and to the contiguous portion of the transversus abdominis.

(*h*) The *superior epigastric artery* (Fig. 553) is the real termination of the internal mammary and extends to the abdomen in the direction of its parent trunk. At the level of the seventh costal cartilage it passes through the space between the costal and sternal portions of the diaphragm and sinks into the substance of the rectus abdominis, which it supplies. Within this muscle numerous small twigs of the vessel anastomose with the inferior epigastric artery from the external iliac, an anastomosis between the artery of the upper and that of the lower extremity being thus brought about. The superior epigastric artery also gives off fine branches which anastomose with branches of the hepatic artery in the falciform ligament of the liver.

The *lateral costal branch* is described as an anomalous branch of the internal mammary artery of occasional occurrence. It is formed by the union of a number of the anterior intercostal branches, usually at the level of the third rib, and passes downward and outward as far as the fifth rib.

3. The **thyreocervical trunk** (Figs. 539, 550, and 551) arises immediately lateral to the vertebral artery from the convexity of the arch of the subclavian. It is a short, thick trunk which usually breaks up into four arteries, although occasionally one or more of these may arise independently from the subclavian artery itself. The direct continuation of the trunk, the *inferior thyreoid artery*, is the largest of these branches, while the other three appear rather as accessory branches. Two of them, the *superficial* and the *ascending cervical arteries*, often arise by a short common stem; the fourth, the *transverse scapular artery*, is a distinctly separate branch of the trunk and is the branch of all others which most frequently springs directly from the trunk of the subclavian.

(*a*) The ***inferior thyreoid artery*** (Figs. 539, 551, 588, and 694) is a rather large vessel, which at first passes vertically upward along the inner margin of the scalenus anterior and behind the common carotid. It then curves medially and, in front of the vertebral artery, passes between the common carotid and the œsophagus to the lateral surface of the trachea and to the thyreoid gland, where it ends in numerous large ***glandular branches*** which enter the posterior aspect of the thyreoid. From one of these twigs proceeds the ***inferior laryngeal artery***, which pierces the lateral wall of the pharynx, gives off ***pharyngeal branches***, and ramifies upon the posterior surface of the larynx, anastomosing with the superior laryngeal artery from the superior thyreoid. The inferior thyreoid artery also gives off ***œsophageal*** and ***tracheal branches.***

(*b*) The ***superficial cervical artery*** (Figs. 539, 550, 588, 699, and 700) at first lies upon the medial surface of the sternocleidomastoideus and of the scalenus anterior, and then runs almost transversely laterally and backward through the supraclavicular fossa, approximately parallel with the clavicle and rather superficial, being covered only by the superficial cervical fascia, the platysma, fatty tissue, and lymphatic glands. It ramifies in the integument and neighboring muscles, usually extending to the trapezius, and may take the place of the ascending branch of the transverse cervical artery when this vessel is unusually small.

(*c*) The ***ascending cervical artery*** (Figs. 539, 550, 551, and 700) passes upward beside the phrenic nerve upon the anterior surface of the scalenus anterior, then passes upon the longus colli. It is covered by the sternocleidomastoideus and the internal jugular vein, and is situated in front of the transverse processes of the cervical vertebræ. It gives ***muscular branches*** to the neighboring muscles and ***spinal branches*** to the vertebral canal. A larger ***deep branch*** is occasionally given off, passing to the nuchal musculature in the region of the fifth cervical vertebra, where it anastomoses with and may sometimes entirely replace the deep cervical artery.

(*d*) The ***transverse scapular*** (***suprascapular***) ***artery*** (Figs. 539, 550, 552, 699, 703, and 704) passes transversely in front of the scalenus anterior to the clavicle, at first running parallel with the superficial cervical artery and then taking a downward direction. It gives off small branches to the neighboring muscles, passes behind the clavicle, sends an ***acromial branch*** through the insertion of the trapezius to the ***acromial rete*** (see page 49), and runs over the superior transverse scapular ligament to reach the supraspinous fossa. It finally passes into the infraspinous fossa between the neck of the scapula and the inferior transverse scapular ligament, supplies the supraspinous and infraspinous muscles and the shoulder-joint, and anastomoses with the circumflex scapular artery from the axillary.

4. The **costocervical trunk** (Fig. 550) arises as a short, thick stem from the posterior surface of the subclavian artery and is of approximately the same caliber as the thyreocervical trunk. It runs upward a short distance behind the scalenus anterior and divides at once into an ascending and a descending terminal branch.

(*a*) The ***superior intercostal artery*** (Fig. 538), the descending terminal, runs downward in front of the neck of the first rib and furnishes the intercostal arteries for the first and second intercostal spaces, these pursuing a course similar to that of the remaining intercostal arteries (see page 53).

(*b*) The ***deep cervical artery*** (Fig. 696), the ascending terminal, which is not always present, passes backward beneath the transverse process of the seventh cervical vertebra and then upward

behind the transverse processes of the cervical vertebræ, between the semispinalis capitis and semispinalis cervicis, to the level of the axis. In addition to numerous *muscular branches* it also sends *spinal branches* through the lower intervertebral foramina of the cervical column to the vertebral canal. The artery anastomoses with branches of the ascending cervical, with the vertebral, with the occipital, and occasionally also with the ascending branch of the transverse cervical.

5. The **transverse cervical artery** (Figs. 539, 552, 696, 699, 700, and 714) is the only branch which arises from the terminal portion of the subclavian, and its size, course, and origin are quite variable. It is situated deeply in the supraclavicular fossa, in front and to the outer side of the scalenus medius, and passes between the cords of the brachial plexus. In front of and lateral to the vessel is the inferior belly of the omohyoideus, as well as lymphatic nodes, fatty tissue, the cervical fascia, and the platysma. It runs laterally and backward, giving off *muscular branches* to the levator scapulæ, and at the anterior margin of the trapezius or somewhat beyond it divides into a smaller ascending and a larger descending branch. The *ascending branch* passes upward between the trapezius and the levator scapulæ or between the latter muscle and the splenius, and anastomoses with the other nuchal arteries according to its degree of development. The *descending branch* runs downward along the vertebral border of the scapula, being situated between the rhomboidei and the serratus posterior superior. It is the largest artery of the back; it anastomoses with numerous branches of the axillary artery and pierces the serratus anterior at the inferior angle of the scapula to reach the subscapular fossa.

When the transverse cervical artery is anomalous, it is most frequently replaced by the superficial cervical, which, under these circumstances, is unusually large.*

THE AXILLARY ARTERY.

The *axillary artery* (Figs. 539, 550, 552, 554, 555, and 703) is the continuation of the subclavian through the axillary fossa. It is accompanied by the vein of the same name, which lies medially and somewhat anterior, and by the brachial plexus which is mostly lateral, but which partly surrounds the artery. The upper portion of the vessel is covered by the clavicular origin of the pectoralis major, the middle portion by the pectoralis major and minor, and the lower portion by the insertion of the pectoralis major, the axillary artery becoming the brachial at the lower margin of the latter muscle. The upper portion of the axillary artery is rather close to the thoracic wall and is in relation medially with the musculature overlying the outer surface of the thorax, particularly with the upper portion of the serratus anterior. The artery then

*[Bean (*Amer. Jour. Anat.*, Vol. IV, 1905) found from a statistical study that the variations in the origin of the branches of the subclavian artery might be referred to five different types. Two of these types included 57 per cent. of the cases examined, one of them, occurring in 22 per cent. of cases on the right side of the body and in only 8 per cent. on the left side, having the inferior thyreoid, transverse scapular, and superficial cervical branches arising from the thyreocervical trunk, while the transverse cervical arises independently from the subclavian behind the scalenus anterior. The other principal type occurred in 22 per cent. of cases on the left side of the body and in only 5 per cent. on the right side, and was characterized by the inferior thyreoid, transverse scapular, and transverse cervical branches arising from the thyreocervical trunk, while the superficial cervical was wanting, its place being taken by small branches from the transverse cervical. In a third type, which occurred in 22 per cent. of cases, and about equally on either side, the thyreocervical trunk gave origin to the inferior thyreoid and superficial cervical branches, the transverse cervical and transverse scapular both arising independently from the subclavian, the former behind the scalenus anterior and the latter distal to it.—ED.]

FIG. 554.—The nerves and vessels of the flexor surface of the upper arm.
FIG. 555.—The same dissection as Fig. 554, after the removal of the veins. The biceps brachii has been drawn outward.

passes away from the thoracic wall toward the arm, where it is at first situated between the insertion of the subscapularis and the coracoid process, and subsequently between the insertion of the subscapularis and the common origin of the coracobrachialis and the short head of the biceps. It leaves the axillary fossa between the tendon of the pectoralis major and those of the latissimus dorsi and teres major, and is separated from the integument of the armpit by a thin layer of fascia and particularly by the axillary lymphatic nodes.

From the axillary cavity the artery supplies branches to the entire region of the shoulder and its ramifications extend not only to the thoracic wall but also to the back. The anterior wall of the axilla is supplied chiefly by the thoraco-acromial artery and its branches, the posterior wall by the large subscapular artery, the inner wall by the lateral thoracic artery, and the outer wall by the circumflex humeral arteries. In their order of origin the branches of the axillary artery are as follows:

1. The **superior thoracic artery** is an inconstant branch. When present it arises from the commencement of the axillary immediately below the subclavius, and passes chiefly to the posterior surface of the pectoralis major, to the pectoralis minor, and to the upper portion of the serratus anterior. When absent the artery is replaced by branches of the following vessel:

2. The **thoraco-acromial artery** (Figs. 539, 551, 552, and 699), the first large branch of the axillary, arises at the upper margin of the pectoralis minor, passes anteriorly to the pectoralis major, which covers it, and after a very short course breaks up into its branches.

(*a*) The *pectoral branches* (Fig. 552), two or three vessels of considerable size, to the pectoralis major and minor.

(*b*) The *acromial branch* (Fig. 552) is covered at its origin by the clavicular portion of the deltoideus, but subsequently becomes superficial and passes to the acromion, where it anastomoses with the acromial branch of the transverse scapular artery to form the *acromial rete*.

(*c*) The *deltoid branch* (Fig. 699) frequently arises with the preceding by a short common trunk. It is superficially situated in the deltoideopectoral trigone and passes downward alongside of the cephalic vein supplying the contiguous margins of the clavicular portions of the deltoid and great pectoral muscles.

3. The **lateral (long) thoracic artery** (Figs. 551, 552, and 594) arises behind the pectoralis minor and runs downward upon the serratus anterior on the lateral thoracic wall to about the level of the fifth intercostal space; it is parallel to the long thoracic nerve although considerably anterior to this structure. The vessel ramifies chiefly in the serratus anterior, where it anastomoses with the branches of the thoracodorsal artery, which also pass to this muscle. It gives off *external mammary branches* to the mammary gland.*

4. The **subscapular artery** (Fig. 703) arises at the lower margin of the insertion of the subscapularis and is the largest branch of the axillary. It forms a short trunk which runs along

*[The lateral thoracic artery, so far as it is a direct branch of the axillary artery, is frequently wanting, its place being taken by a large branch either from the thoraco-acromial or the subscapular artery.—ED.]

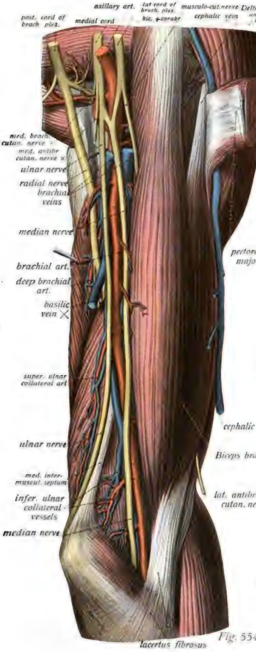

Fig. 554.

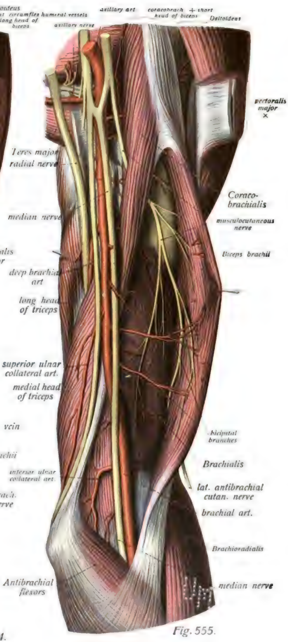

Fig. 555.

the lower border of the subscapularis, gives off some twigs to this muscle, and divides into two large branches:

(*a*) The ***thoracodorsal artery*** (Figs. 552, 594, and 703) continues in the direction of the parent trunk, runs along the teres major and latissimus dorsi parallel to the axillary border of the scapula, giving off branches to these muscles, and to the subscapularis and serratus anterior, and anastomoses with the lateral thoracic artery.

(*b*) The ***circumflex (dorsal) scapular artery*** (Figs. 594, 703, and 704), the second terminal of the subscapular, passes through the triangular space bounded by the teres major, the teres minor (or the subscapularis), and the long head of the triceps, and curves around the axillary border of the scapula to reach the posterior aspect of the shoulder. In addition to supplying the subscapularis, teres major, and teres minor, the artery sends branches to the infraspinatus, being situated between this muscle and the dorsal surface of the scapula, and anastomoses with the transverse scapular artery from the subclavian by branches which pass about the neck of the scapula to reach the supraspinous fossa.

5. The **subscapular branches** are independent arteries which pass from the axillary to the subscapularis muscle.

6. The **anterior circumflex humeral artery** (Fig. 703) is a relatively insignificant vessel which arises at the level of the upper margin of the tendon of insertion of the pectoralis major, passes outward around the anterior surface of the surgical neck of the humerus, covered by the coracobrachialis, the short head of the biceps, the long tendon of the triceps, and the deltoideus, and supplies these muscles and the shoulder-joint.

7. The **posterior circumflex humeral artery** (Figs. 594, 703, and 704) is much larger than the preceding vessel. It arises at the level of the upper border of the tendon of insertion of the latissimus dorsi, opposite the origin of the anterior circumflex artery, and passes backward around the surgical neck of the humerus, through the quadrilateral space bounded by the teres major, the long head of the triceps, the lower border of the subscapularis and the bone, to reach the posterior aspect of the shoulder in company with the axillary nerve. The artery is separated from the circumflex scapular artery by the long head of the triceps and is covered by the deltoideus, which it supplies, as well as the long head of the triceps and articular capsule of the shoulder-joint, and anastomoses freely with the deltoid branch of the thoraco-acromial, with the anterior circumflex, and with the subscapular.

The region of the shoulder is chiefly supplied by branches of the subclavian and axillary arteries, which anastomose freely and are useful in forming a collateral circulation when the blood-stream in the main channel has been interrupted. The most important of these anastomoses are: (1) The ***transverse scapular***, from the subclavian, anastomoses with the ***circumflex scapular***, from the axillary, in the supraspinous and infraspinous fossæ. (2) The ***transverse scapular***, from the subclavian, anastomoses by means of its acromial branch with the similarly named branch of the ***thoraco-acromial artery*** to form the acromial rete. (3) The descending branch of the ***transverse cervical***, from the subclavian, anastomoses with branches of the ***thoracodorsal*** and ***circumflex scapular*** arteries, from the axillary. The individual branches of the axillary artery also enter into manifold anastomoses—*e.g.*, (*a*) The deltoid branch of the ***thoraco-acromial*** with the posterior circumflex artery of the humerus; (*b*) the ***lateral thoracic*** with the thoracodorsal; (*c*) the two ***circumflex humeral arteries*** with each other; (*d*) the ***posterior circumflex humeral*** with the ***subscapular*** and ***circumflex scapular*** arteries. Other anastomoses exist between several of the branches of the axillary artery passing to the thoracic wall (the lateral thoracic, the thoracodorsal) and the lateral cutaneous branches of the aortic intercostals. Finally, the long head of the triceps contains anastomoses between the branches of the posterior circumflex humeral artery and twigs of the deep brachial artery from the brachial itself.

FIG. 556.—The nerves and vessels of the extensor surface of the upper arm (superficial layer).
FIG. 557.—The nerves and vessels of the extensor surface of the upper arm (deep layer).
* = Divided twig of deltoid branch of deep brachial artery. ** = A portion of the triangular space.

THE BRACHIAL ARTERY.

The *brachial artery* (Figs. 554 to 557 and 705 to 707), the immediate continuation of the axillary, runs in the medial bicipital sulcus immediately beneath the fascia, the subcutaneous veins and nerves, and the integument. It passes almost directly downward into the cubital fossa, in the depths of which it divides into its two terminal branches—the radial and the ulnar arteries. As it lies in the medial bicipital sulcus the artery has a number of important relations in addition to that with the biceps. At its commencement it is medial to the insertion of the coracobrachialis, lower down it is situated in front of the brachialis, and the termination of the artery rests upon the insertion of the brachialis and is covered by the lacertus fibrosus. The site of bifurcaton is in front of the insertion of the brachialis, between the pronator teres and the tendon of insertion of the biceps, and corresponds to the level of the coronoid process of the ulna. The artery is accompanied by two brachial veins and by the median nerve, the latter structure being at first lateral, crossing the artery at an acute angle below the middle of the arm, and finally taking a medial position in the cubital fossa. In the upper third of the arm the ulnar nerve is near the medial surface of the artery.

But few large branches are given off by the brachial artery. With the exception of ten or twelve *muscular branches* (particularly to the biceps) it gives origin to the following three vessels, of which the first is the only one of considerable size:

1. The **deep brachial (superior profunda) artery** (Figs. 554 to 557) arises as a short thick trunk in the neighborhood of the upper border of the medial head of the triceps and approaches the radial nerve, which it accompanies at first between the long and medial heads of the triceps and then between the medial and lateral heads, in the groove for the radial nerve upon the posterior surface of the humerus. It is the artery for the posterior surface of the arm, in which situation it divides into its terminals. In addition to muscular branches to the triceps it gives off:

(*a*) The *deltoid branch* (Figs. 556 and 557), a small vessel, occasionally absent, which goes to the lower and posterior portion of the deltoideus.

(*b*) The *nutrient arteries of the humerus*, several small branches which enter the bone through corresponding nutrient foramina.

(*c*) The *middle collateral artery*, one of the terminals, usually penetrates the substance of the inner head of the triceps and runs in this muscle to the cubital articular rete (see page 49).

(*d*) The *radial collateral artery* (Figs. 556 to 558 and 709), the second terminal of the deep brachial and its actual continuation, accompanies the radial nerve in its groove and soon divides into a volar and a dorsal branch. The volar branch passes with the radial nerve to the anterior surface of the elbow and is situated in the groove between the brachioradialis and the brachialis; upon the supinator it anastomoses with the radial recurrent artery. The dorsal branch appears at the external intermuscular septum together with the dorsal cutaneous antibrachial nerve,

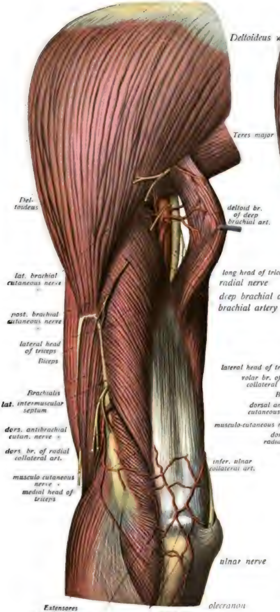

Fig. 556.

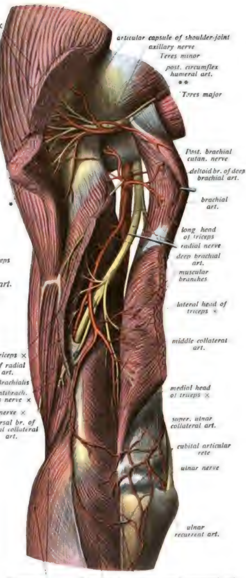

Fig. 557.

and ramifies in the triceps and in the integument upon the posterior surface of the arm, terminating in the cubital articular rete.

2. The **superior ulnar collateral (inferior profunda) artery** (Figs. 554 to 557 and 705) arises some distance below the deep brachial and accompanies the ulnar nerve along the medial intermuscular septum as far as the olecranon, giving off branches to the medial head of the triceps and terminating in the cubital articular rete.

3. The **inferior ulnar collateral (anastomotica magna) artery** (Figs. 554 to 557 and 705 to 707) arises far below the preceding vessels, just above the internal condyle, and runs downward and medially in front of the inner portion of the brachialis toward the lower part of the medial intermuscular septum, which it pierces to reach the inferior humeral epiphysis. It gives off numerous muscular branches, and terminates by anastomosing with the preceding vessels and with the ulnar recurrent arteries in the cubital articular rete.

The branches of the brachial artery are subject to manifold variations. Either ulnar collateral artery may replace its fellow or they may both arise from the deep brachial, together with branches of the axillary artery (the subscapular and the circumflex humeral arteries). In Fig. 557 a variant of the origin of the terminals of the deep brachial is shown.

THE ARTERIES OF THE FOREARM.

It is usually stated that the brachial artery divides in the cubital fossa into two terminal branches—the *radial* and the *ulnar* arteries (Figs. 558, 559, and 705 to 709). It would be more accurate to say that the brachial artery gives off a large branch in the cubital fossa, the radial artery, and then runs a short distance before dividing into its terminal branches—the ulnar artery (in a restricted sense) and the common interosseous artery. This conception is supported by some of the numerous anomalies of the arteries of the forearm.

The radial artery supplies the radial side of the anterior surface and the radial border of the forearm, passes to the back of the hand to form its chief artery, and is also concerned in the supply of the palm. The ulnar artery by means of its interosseous branch supplies the posterior surface of the forearm, the vessel itself supplying the ulnar border and the ulnar half of the anterior surface, and also forming the chief artery of the palm. But few branches of the ulnar artery reach the back of the hand and these do not extend any great distance beyond the wrist. All the proximal branches of both the radial and ulnar arteries participate in the formation of the cubital articular rete.

In scarcely any other location in the body are anomalies so frequent as in the arteries of the forearm. The most important is a high division of the brachial—*i.e.*, the radial artery arises at some point in the upper arm and pursues a superficial course to the forearm, frequently being situated even in front of the lacertus fibrosus. Sometimes an artery branches off from the brachial and subsequently unites with it in the cubital fossa (vas aberrans); if it join the radial artery in this situation the first-mentioned anomaly is produced. More rarely the ulnar artery arises in this manner and runs superficially, in front of the superficial flexors, the vessel then corresponding only to the ulnar artery in the restricted sense, while the common interosseous artery represents the termination of the trunk of the brachial. This latter condition may also obtain when the radial artery and the ulnar artery in the restricted sense arise from a common superficial trunk. Not infrequently the small median artery is replaced by a large vessel, which then supplies the hand as a third artery of the forearm.

[The majority of these anomalies are probably to be regarded as persistences of conditions occurring in the embryo. Thus, at an early stage of development but a single artery occurs in the forearm, the brachial being continued directly downward as the interosseous artery. From this arises secondarily the median artery, which for a time is the principal artery of the forearm, and finally the ulnar artery is formed. From the brachial, high in the upper arm, arises a superfi-

cial brachial stem, which passes down the radial side of the forearm and later makes a connection with the interosseous at the point where this vessel gives origin to the ulnar. The upper part of the superficial brachial then normally degenerates, being represented in the adult only by a muscular branch, and its lower part becomes the radial. Should the original superficial brachial persist, however, a high origin of the radial would result. A high origin of the ulnar might be due to a secondary connection of the original ulnar stem with the superficial brachial, and the occurrence of a large median artery is a simple persistence of that vessel in its embryonic condition.—Ed.]

THE RADIAL ARTERY.

The *radial artery* (Figs. 705 to 709) arises behind the lacertus fibrosus from the bifurcation of the brachial, and pursues a fairly straight course toward the wrist-joint. At first it lies between the insertion of the biceps and the lacertus fibrosus, then between the brachioradialis and the supinator, and lower down, behind the brachioradialis and in front of the insertion of the pronator radii teres. Up to this point it is beneath the inner portion of the brachioradialis, but below the middle of the forearm it is covered only by skin and fascia and lies in the groove between the brachioradialis and the flexor carpi radialis, consequently at the inner (ulnar) margin of the former. Behind the artery in this situation are the flexor pollicis longus and the pronator quadratus. With the brachioradialis and accompanied by the superficial branch of the radial nerve which lies upon its radial side, the radial artery passes downward to the region of the styloid process of the radius, this part of its course being that in which the pulse is usually taken. From here the artery passes to the back of the hand (Figs. 560 and 561) between the radius and the tendons of the abductor pollicis longus and extensor pollicis brevis, runs through the radial foveola (the anatomic snuffbox), and passes through the first interosseous space to reach the depths of the palm, where its terminal ramification takes place.

The most important branches of the radial artery are given off either from its commencement or, more especially, from its terminal portion. The long middle portion gives origin to muscular branches only.

1. The *recurrent radial artery* (Figs. 705 to 707 and 709) arises from the commencement of the artery, passes backward and upward (proximally) between the supinator upon one side and the brachioradialis and extensor carpi radialis longus upon the other, ramifies in the contiguous muscles, anastomoses with the volar branch of the radial collateral artery, and terminates in the cubital articular rete (see page 49).

2. The *muscular branches* (Figs. 705 to 707) are quite numerous. They arise from the entire length of the radial artery and supply the neighboring muscles.

3. The *superficial volar branch* (Figs. 562, 563, and 705 to 707) arises at the upper margin of the styloid process and pursues a superficial course into the palm, being covered either only by the fascia and, in some cases, also by the abductor pollicis brevis. It gives muscular branches to the thenar eminence and joins the ulnar artery to form the superficial volar arch (see page 51).

4. The *volar carpal branch* (Fig. 563) is a small and somewhat inconstant vessel which passes between the tendon of the flexor carpi radialis and the volar surface of the lower extremity of the radius to join the volar carpal rete.

Upon the back of the hand arises:

5. The *dorsal carpal branch* (Figs. 560 and 561) is the only large vessel which takes origin

upon the back of the hand. It is occasionally double and forms the chief source of supply of the dorsal carpal rete.

6. Subject to great variation, but usually coming directly from the trunk of the radial, are the small dorsal arteries which go to both sides of the thumb and to the radial side of the index-finger, the *radial* and *ulnar dorsal digital arteries* of the thumb and the *radial dorsal digital artery* of the index-finger (Fig. 560). The two latter vessels may arise from a short common trunk, which is then designated as the *first dorsal metacarpal artery*.

In the palm and between the first dorsal interosseous muscle and the adductor pollicis the radial artery divides into its two terminal branches.

7. The *princeps pollicis* (Figs. 560, 561, and 563) is the common artery for both volar margins of the thumb and for the radial side of the index-finger, giving off the *radial* and *ulnar volar digital arteries* of the thumb and the *radial volar digital artery* of the index-finger. These branches are variable inasmuch as they may be partly or wholly replaced from the superficial palmar arch. The artery runs along the volar surface of the metacarpal bone of the thumb.

8. The second and actual terminal branch of the radial artery forms the *deep volar arch* (see page 51).

THE ULNAR ARTERY.

The *ulnar artery* (Figs. 707 and 708) arises in the cubital fossa from the bifurcation of the brachial (see page 45), and at its origin is not much larger than the radial, although after giving off its proximal branches its caliber is practically the same as that of this vessel. It runs downward to the wrist upon the ulnar side of the forearm and holds a relation to the flexor carpi ulnaris similar to that of the radial artery to the brachioradialis. Throughout the forearm, however, the ulnar artery is more deeply situated than the radial.

The vessel, which at first seems to be the direct continuation of the brachial, makes a gentle curve to the ulnar side, and at first, accompanied by the median nerve, lies in front of the insertion of the brachialis and at the ulnar border of the insertion of the biceps and then upon (in front of) the flexor digitorum profundus, being covered in the latter situation by the origins of the superficial flexors and of the pronator teres. In front of the flexor digitorum profundus it passes almost directly downward, and at the same time takes up a position in the groove between the flexor carpi ulnaris and the flexor digitorum sublimis. In this part of its course the artery is accompanied by the ulnar nerve, which lies in contact with it upon its ulnar side. The artery becomes more superficial as it passes downward to the pisiform bone, at the radial margin of the tendon of the flexor carpi ulnaris. It next passes over the transverse carpal ligament immediately to the radial side of the pisiform bone and enters the palm, where it is covered by the fascia and the palmaris brevis, and forms the superficial volar arch immediately beneath the palmar aponeurosis. The branches of the ulnar artery are:

1. The **recurrent ulnar arteries** (Figs. 558 and 706 to 708), usually two in number, may also arise by a common trunk. The smaller and anterior vessel passes in front of the medial epicondyle of the humerus to the muscles arising in this region. The larger and posterior artery runs behind the medial epicondyle, gives off muscular branches, and passes between the heads of the flexor carpi ulnaris above the ulnar nerve to reach the cubital articular rete.

FIG. 558.—The superficial layer of the nerves and vessels of the extensor surface of the forearm.
The extensor digitorum communis and extensor digiti quinti have been drawn slightly to one side.

FIG. 559.—The deep layer of the vessels and nerves of the extensor surface of the forearm.
The extensor digitorum communis and extensor digiti quinti have been strongly retracted toward the ulnar side, the extensor pollicis longus divided, and the supinator incised for a short distance along the deep branch of the radial nerve.

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2. The **common interosseous artery** (Figs. 706 and 707) is the largest and most important branch of the ulnar, and may arise directly from the brachial when the origin of the ulnar is anomalous. It is a short, thick trunk which springs from the posterior surface of the ulnar artery below the tuberosity of the ulna and divides immediately into its two terminal branches. These are:

(*a*) The *dorsal interosseous artery* (Figs. 558, 559, and 707), which passes above the upper margin of the interosseous membrane through the interosseous space to reach the dorsal surface of the forearm, where it gives off the *interosseous recurrent artery*. This latter vessel runs beneath the anconæus, gives off several twigs which pierce the muscle, and enters the cubital articular rete. The dorsal interosseous artery itself passes downward between the superficial and the deep groups of the extensors of the forearm, ramifies in all the muscles of these layers, and sends terminal branches as far as the dorsal carpal rete.

(*b*) The *volar interosseous artery* (Figs. 558, 559, 561, and 707) runs downward upon the volar surface of the interosseous membrane, covered by the flexor digitorum profundus and the flexor pollicis longus. It supplies the overlying muscles, the radius, the ulna, and gives off branches which pierce the membrane and supply the deeper extensor muscles. A branch, which is usually very slender, passes to the median nerve and pursues a markedly tortuous course downward upon the nerve as the *median artery*. This vessel is not infrequently large enough to form a third artery of the forearm. The volar interosseous artery ramifies in the pronator quadratus and also sends fine branches to the volar carpal rete. The actual termination of the vessel, however, pierces the interosseous membrane at the level of the pronator quadratus, applies itself closely to the dorsal surface of the distal extremity of the membrane, gives off muscular twigs to the deep extensors, and ends in the dorsal carpal rete.

During its course in the forearm the ulnar artery gives off the following branches:

3. **Muscular branches** (Fig. 707), which are numerous, some arising even in the cubital fossa, and which supply particularly the pronator teres and the flexor carpi ulnaris.

4. The **dorsal carpal branch** (Figs. 560 and 561) arises above the wrist-joint, winds around the ulna above the capitulum to reach the dorsal surface of the carpus, aids in the formation of the dorsal carpal rete, and gives off the ulnar dorsal digital artery of the little finger.

In the region of the carpus the following branches arise from the ulnar artery:

5. The *volar carpal branch* (Fig. 563) is covered by the tendons of the flexor digitorum profundus and goes to the volar carpal rete.

6. The *deep volar branch* (Figs. 562 and 563), together with the deep volar branch of the ulnar nerve, passes between the muscles of the hypothenar eminence into the palm, where it takes part in the formation of the deep volar arch.

7. The actual termination of the ulnar artery forms the principal portion of the *superficial volar arch* (see page 51).

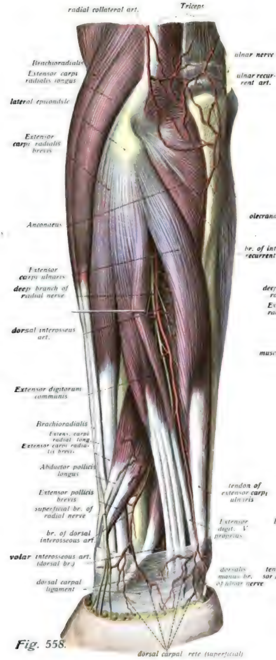

Fig. 558.

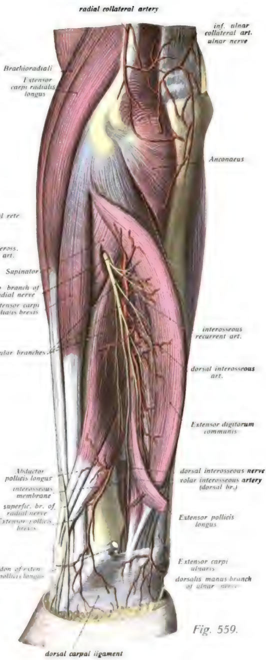

Fig. 559.

THE ARTICULAR RETIA OF THE UPPER EXTREMITY.

The Acromial Rete.—The acromial rete (Fig. 704) is superficially placed between the acromion and the fibers of the platysma and skin of the shoulder, and is practically formed by the anastomoses of the acromial branch of the transverse scapular artery from the subclavian with the acromial branch of the thoraco-acromial artery from the axillary.

The Cubital Articular Rete.—The cubital articular rete (Figs. 558 and 559) is one of the largest articular networks of the body. It is composed of a superficial network situated over the humeral epicondyles, the posterior surface of the triceps tendon, and the olecranon (olecranal rete), and of a deeper one situated between the triceps tendon and the posterior surface of the articular capsule. The arteries sending branches to the rete arise partly proximal to the joint and take a distal direction to reach the rete and partly distal to the joint and pursue a proximal course. The proximal roots of the cubital rete are: (1) The *radial* and *middle collateral arteries* from the deep brachial. (2) The *superior* and *inferior ulnar collateral arteries* from the brachial. The distal roots are: (1) The *radial recurrent artery* from the radial. (2) The *interosseous recurrent* from the dorsal interosseous. (3) The *recurrent ulnar arteries* from the ulnar. Not only are the distal and the proximal branches of the same side connected with each other, but transverse anastomoses also take place between the radial and the ulnar branches.

The Volar Carpal Rete.—The volar carpal rete (Fig. 563) is a small network situated deeply in the carpal canal, in immediate contact with the articular capsules and ligaments of the volar surface of the carpal bones. The vessels entering into it are of small size and are practically all derived from the proximal side. They are: (1) Twigs from the volar terminal branch of the volar interosseous artery. (2) The *volar carpal branch* of the radial artery. (3) The *volar carpal branch* of the ulnar artery. From the distal side the volar carpal rete receives small recurrent twigs from the deep volar arch.

The Dorsal Carpal Rete.—The dorsal carpal rete (Figs. 560 and 561) is much larger than the preceding. It is partly superficial, between the dorsal carpal ligament and the skin, but the greater portion is deeply situated between the dorsal surface of the carpal joints and the tendons of the extensors. The following arteries and twigs enter into its formation: (1) The *dorsal interosseous artery* usually ends by means of very small branches which pass to the superficial portion of the rete. (2) The dorsal terminal branch of the volar interosseous artery forms a considerable source of supply to the deep portions of the network. (3) The *dorsal carpal branch* of the ulnar artery is concerned in the formation of the ulnar half of the rete. (4) The largest afferent vessel is the *dorsal carpal branch* of the radial, which also supplies the majority of the dorsal arteries of the hand given off by the dorsal carpal rete (see page 46).

THE ARTERIES OF THE HAND.

The arteries of the hand (Figs. 560 to 563, and 712) are not distributed equally to the dorsum and to the palm, the latter being by far the more richly supplied, and the volar arteries also nourish the dorsal surfaces of the finger-tips. The volar branches of the radial and ulnar arteries form curved anastomoses, which are known as the *superficial* and *deep volar arches*, the former being chiefly supplied by the ulnar artery, while the latter is practically supplied by the radial. Both

FIG. 560.—The arteries of the dorsum of the hand (superficial layer).

The fascia has been removed.

FIG. 561.—The arteries of the dorsal surfaces of the hand and of the lower extremity of the forearm.

The tendons of the extensors, with the exception of those of the abductor pollicis longus and extensor pollicis brevis, have been divided and partly removed. The greater portion of the dorsal carpal ligament has been cut away. * = Twigs of a volar digital artery. ** = Twigs of volar digital nerves reflected to the dorsal surface. + = Entrance of radial artery into the palm.

FIG. 562.—The arteries and nerves of the palm (middle layer).

The palmar aponeurosis has been removed and the abductor pollicis brevis divided along the superficial volar branch of the radial artery. * = Anastomosis between median and ulnar nerves.

FIG. 563.—The arteries and nerves of the palm (deep layer).

The abductor and abductor pollicis and the flexor digiti quinti have been divided; the tendons of the flexors, the median nerve, the superficial volar branch of the ulnar nerve, and the superficial volar arch have been removed.

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arches give off arteries which course longitudinally through the palm to the fingers; those given off from the superficial arch are termed the *common volar digital arteries*, while those from the deep arch are called the *volar metacarpal arteries*. The dorsal arteries are known as the *dorsal metacarpal arteries*, and are furnished chiefly by the dorsal carpal rete.

Each finger receives four arteries, two small *dorsal digitals* and two larger *proper volar digitals*, the dorsal vessels usually arising from the dorsal metacarpal arteries, while the majority of the proper volar digital arteries are derived from the bifurcation of the common volar digital arteries. In the radial and ulnar margins of every finger there is a dorsal and a volar artery, so that there is both a *radial* and an *ulnar proper volar digital artery* and a *radial* and an *ulnar dorsal digital artery* in each digit. The dorsal arteries of the fingers extend only to the proximal end of the middle phalanx, the distal extremity of this phalanx and the terminal phalanx being supplied by the volar arteries.

THE ARTERIES OF THE DORSUM OF THE HAND.

The arteries of the back of the hand (Figs. 560 and 561) are derived almost entirely from the radial, only the ulnar border of the dorsum being supplied by the ulnar. Passing from the radial to the ulnar side the following arteries should be noted:

1. The **radial dorsal digital artery of the thumb** from the radial artery (see page 47).

2. The **ulnar dorsal digital artery of the thumb**, also a direct branch of the radial (see page 47).

3. The **radial dorsal digital artery of the index-finger**, which is also an immediate branch of the radial (see page 47).

4. The **second, third**, and **fourth dorsal metacarpal arteries** arise indirectly from the dorsal carpal branch of the radial through the dorsal carpal rete, and run along the dorsal surfaces of the dorsal interossei, ramifying in these muscles and in the immediate vicinity. They receive the perforating branches of the volar metacarpal arteries and, thus reinforced, each vessel divides near the head of the corresponding metacarpal bone into two dorsal digital arteries, thus supplying—

(*a*) The *ulnar dorsal digital artery of the index digit.*

(*b*) The *radial dorsal digital artery of the third digit.*

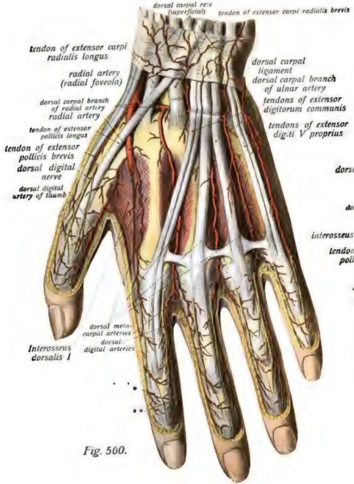

Fig. 500.

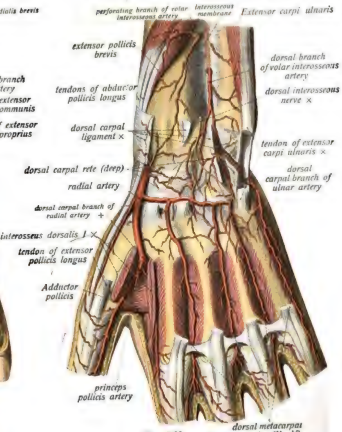

Fig. 561.

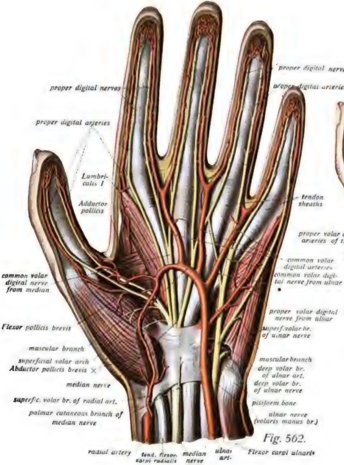

Fig. 562.

Fig. 563.

(*c*) The *ulnar dorsal digital artery of the third digit.*

(*d*) The *radial dorsal digital artery of the fourth digit.*

(*e*) The *ulnar dorsal digital artery of the fourth digit.*

(*f*) The *radial dorsal digital artery of the fifth digit.*

5. The **ulnar dorsal digital artery of the fifth digit** is the termination of the dorsal carpal branch of the ulnar artery (see page 48).

THE ARTERIES OF THE PALM.

The arteries of the palm (Figs. 562, 563, and 712) arise from the two palmar arches, formed by the anastomoses of the radial and ulnar arteries. Both arches are distally convex, the superficial arch being the more distal, the deep the more proximal; both arches are in the metacarpal region.

The Superficial Volar Arch.—The superficial volar arch (Fig. 562) is situated immediately beneath the palmar aponeurosis, between this structure and the synovial sheaths of the tendons of the flexor digitorum sublimis and profundus. The arch is convex toward the fingers, concave toward the carpus, and is situated at about the middle of the palm, the greatest convexity being about 2 cm. from the distal border of the transverse carpal ligament. It is formed by the anastomosis of the terminal branch of the ulnar artery with the superficial volar branch of the radial. The ulnar extremity of the arch is twice as thick as the radial, indicating that the arch is chiefly (occasionally wholly) supplied by the ulnar artery. In addition to small branches to the vicinity, to the ball of the thumb, to the lumbricales, and connecting twigs to the branches of the princeps pollicis, the superficial volar arch gives off:

1. The second, third, and fourth *common volar digital arteries* (Figs. 562 and 723) are of large size, covered by the palmar aponeurosis, and, together with the common volar digital nerves from the median, pass to the region of the heads of the metacarpal bones, where each vessel divides into a *radial* and an *ulnar proper digital volar artery* for the contiguous margins of the fingers. The site of division is distal to the transverse fasciculi of the palmar aponeurosis, so that the arteries are here visible in the spaces between the slips of the palmar aponeurosis and covered only by fatty tissue.

2. The *ulnar volar digital artery of the fifth digit* frequently arises in common with the deep volar branch (see page 48), and passes to the ulnar border of the little finger.

The Deep Volar Arch.—The deep volar arch (Fig. 563) is formed by the junction of the terminal portion of the radial artery with the deep volar branch of the ulnar artery. In contrast to the superficial arch, its radial extremity is much thicker than the ulnar, the deep arch being supplied chiefly by the radial artery. It is not so sharply curved as the superficial arch, but is somewhat longer and distally convex, and it is also more proximal, being situated upon the volar interossei and covered by the adductor pollicis and the synovial sheaths of the flexor tendons. In addition to small branches to the neighboring muscles and joints and recurrent branches to the volar carpal rete, the deep volar arch gives off the first, second, third, and fourth *volar metacarpal arteries.* The two radial (the first and the second) arteries are usually larger than the two ulnar vessels. The first (the *radialis indicis*) runs over the volar surface of the first dorsal interosseous muscle to the radial margin of the index-finger, supplying the muscle

and anastomosing with twigs of the princeps pollicis. The other three run distally upon the volar surfaces of the volar interossei, in which they ramify, and reinforce the common volar digital arteries in the neighborhood of the heads of the metacarpal bones. They are also connected with the dorsal metacarpal arteries by means of *perforating branches* which pass through the interosseous spaces just in front of the bases of the metacarpal bones.

The distribution of the arteries of the hand as above described may be regarded as the normal, although it occurs in exactly this manner in scarcely one-half of all cases, anomalies of varying degree being usually present. If a large median artery extends into the palm it takes an important part in the formation of the superficial volar arch. On the other hand, if the superficial volar branch of the radial artery be absent, the superficial volar arch may be poorly developed or even entirely absent, the common volar digital arteries then being the simple terminal branches of the ulnar artery. The deep arch is more rarely incomplete. Of special frequency are slight variations in the origin and distribution of the radial and ulnar marginal arteries, especially the princeps pollicis, which may seem to be rather a first common volar digital artery or may be largely replaced by the first volar metacarpal artery.

THE THORACIC PORTION OF THE DESCENDING AORTA. THE THORACIC AORTA.

The *thoracic aorta* (Figs. 368, 369, 538, and 726) commences at the termination of the aortic arch at the level of the body of the fourth thoracic vertebra, and extends downward to the level of the twelfth thoracic vertebra, where it passes through the aortic opening to become the abdominal aorta. It lies at first to the left of the bodies of the vertebræ, but it is soon crossed by the œsophagus at an acute angle (see Vol. II, page 44) and approaches the median line, so that in the lower thoracic region it is situated upon the anterior surface of the vertebral bodies just to the left of the median line, and it pierces the diaphragm in this location. Since it pierces the diaphragm obliquely there is more of its posterior than of its anterior wall in the thoracic cavity.

Throughout its entire length the thoracic aorta is situated in the posterior mediastinal cavity, close to the left posterior mediastinal lamina, which is bulged forward by the aorta. The œsophagus is at first to the right, then in front, and finally to the left, and the thoracic duct is to the right above, while lower down it is behind. The uppermost portion of the thoracic aorta is behind the root of the left lung; to the right and in fairly close proximity is the vena azygos, and anteriorly is the pericardium.

In contrast to the aortic arch the thoracic aorta gives off only relatively small branches. The visceral branches to the thoracic organs are quite insignificant and very variable; of the parietal branches the intercostal arteries, which are arranged in pairs, are by far the largest and most important.

THE VISCERAL BRANCHES.

1. The *right* and *left bronchial arteries* (Fig. 538) are rather variable as to their origins. They may arise from the concavity of the aortic arch, from the first portion of the thoracic aorta, or from one of the upper (the third or the fourth) intercostal arteries coming from the aorta. The last-named origin is of frequent occurrence, particularly upon the right side. The bronchial arteries run along the posterior walls of the bronchi, which they accompany to the root of the lung, and ramify within the lung along the bronchial rami. They also send small twigs to the œsophagus, to the pleura, and to the pericardium.

2. The *œsophageal arteries* (Fig. 538) are from three to five small branches, which arise

at different levels from the thoracic aorta and supply the entire length of the thoracic portion of the œsophagus.

3. The *pericardiac branches* pass to the pericardium; only a few arise from the thoracic aorta, the majority coming from the two preceding groups of arteries.

THE PARIETAL BRANCHES.

1. The **mediastinal branches** are small but numerous, and supply the vessels, the nerves, the lymphatic nodes, and the walls of the posterior mediastinum. Some of them arise directly from the aorta, but the majority come from the œsophageal and the intercostal arteries. Some of the lower mediastinal branches supply the upper surface of the lumbar portion of the diaphragm and are known as the *superior phrenic arteries*.

2. **The Intercostal Arteries** (Figs. 538 and 587).—The thoracic aorta usually gives rise to ten pairs of these vessels, the third to the twelfth right and left intercostal arteries, the upper two originating from the subclavian (see page 40). The arteries arise from the posterior surface of the aorta, each close to its fellow of the opposite side, and correspond to the intercostal spaces, in which they run, except the twelfth, which runs along the lower border of the last rib. The upper intercostal arteries are the smallest, the lower ones the largest. The third and fourth occasionally arise by a common trunk, in which case the aorta gives off but nine pairs of vessels.

The intercostal arteries supply the thoracic wall, the upper abdominal wall, and parts of the back. The left and the right arteries are of unequal length and differ somewhat in the first portions of their course, since the thoracic aorta is situated to the left side of the vertebral column. The left intercostals run almost horizontally on the left surfaces of the vertebral bodies to reach the heads of the ribs; the right arteries, especially the upper ones, pass at first rather sharply upward, cross the anterior surface of the vertebral bodies obliquely, and do not run horizontally until they reach the right surfaces of the vertebral bodies. In front of the right intercostal arteries are the thoracic duct, the vena azygos, the œsophagus, and the sympathetic trunk; in front of the left, only the vena hemi-azygos and the left sympathetic.

Beyond the heads of the ribs the course of the arteries is exactly the same upon both sides. At the lower margin of the head of the rib each divides into a small *posterior branch* and a larger *anterior branch*, the latter being the direct continuation of the trunk and, from its course, the actual intercostal artery.

(*a*) The *posterior branch* passes backward between the neck of the rib and the transverse process of the thoracic vertebra, sends a *spinal branch* through the intervertebral foramen into the vertebral canal to the spinal cord, to the dura mater, and to the vertebra itself, supplies the deeper layers of the muscles of the back with *muscular branches*, and the integument of the back with *internal* and *external dorsal cutaneous branches*.

(*b*) The *anterior branch* (Fig. 538), the actual intercostal artery, runs in the middle of the intercostal space in front of the external intercostal muscles to the vicinity of the angle of the rib. Beyond this point it runs in the costal groove on the lower border of the rib, between the external and the internal intercostal muscles, and gives off a parallel branch to the upper border of the next lower rib, so that there is an artery upon the upper and the lower border of every rib, the vessel at the lower border, however, being much the larger. *Muscular branches* are given

off by both vessels, especially by the larger upper one, passing to the intercostal muscles and to the diaphragm, and, from the lower intercostal arteries, to the abdominal muscles and the lower portion of the pectoralis major.

The intercostal arteries also give off two series of cutaneous branches—the lateral and the anterior. The lateral cutaneous branches pierce the external intercostal muscles in the lateral portion of the thoracic wall and reach the skin between the digitations of the serratus anterior. According to the level at which they make their exits they are subdivided into the *pectoral* and *abdominal lateral cutaneous branches*, and, in correspondence with the accompanying branches of the intercostal nerves, they divide into a *posterior branch* for the dorsal integument and an *anterior branch* for skin of the chest. The anterior branches of the third to the fifth or sixth lateral cutaneous arteries give off lateral *mammary branches* to the mammary gland.

The *anterior cutaneous branches* pass through the anterior portions of the intercostal spaces, perforating the external intercostal muscles and the sternocostal portion of the pectoralis major medial to the nipple, and are similarly subdivided according to the level of their exits into the *pectoral* and the *abdominal anterior cutaneous branches*. The former give off the *medial mammary branches* to the mammary gland; they are small and inconstant and are usually absent above and below.

The anterior extremities of the anterior branches of the intercostal arteries anastomose with the intercostal branches of the internal mammary artery, and the lower ones also with the lumbar arteries.

THE ABDOMINAL PORTION OF THE DESCENDING AORTA.

THE ABDOMINAL AORTA.

The *abdominal aorta* (Figs. 413 and 716) commences at the termination of the thoracic aorta at the aortic opening in the diaphragm in front of the twelfth thoracic vertebra, and extends downward to the lower margin of the fourth lumbar vertebra. In this situation it divides into the two common iliac arteries and gives origin to a third, but much smaller vessel, the middle sacral artery, which passes downward over the anterior surface of the fifth lumbar vertebra and of the sacrum, and represents the actual continuation of the trunk.

The abdominal aorta lies upon the anterior surfaces of the bodies of the four upper lumbar vertebræ, somewhat to the left of the median line, but nevertheless almost median. It is retroperitoneal and behind the stomach, the pancreas, the inferior portion of the duodenum, and a portion of the root of the mesentery. To the right side is situated the inferior vena cava, which in its upper part, however, is not in immediate contact with the aorta. Since large vascular trunks for the abdominal viscera originate from the abdominal aorta, it rapidly diminishes in caliber, especially in its upper third.

The branches of the abdominal aorta may be divided into the *visceral branches* and the *parietal branches*, the former being by far the larger. The majority of the branches arise from the upper third of the aorta, some arising from its commencement. The largest visceral branch, the cœliac artery, as well as two small parietal branches, the inferior phrenic arteries, arise at the level of the twelfth thoracic vertebra; scarcely more than 1 cm. below these vessels arises

the next to the largest visceral branch, the superior mesenteric artery, and at about the same level are given off two parietal branches, the first pair of lumbar arteries, and lower down the remaining pairs, four in all, which arise like the intercostal arteries from the posterior surface of the aorta, one pair at the level of each of the four upper lumbar vertebræ. Below the superior mesenteric artery are the renal arteries, above them the middle suprarenal arteries, and at the level of the second lumbar vertebra the internal spermatic arteries. Below this point no vessel of considerable size is given off until the inferior mesenteric artery is reached, this taking origin at the disc between the third and the fourth lumbar vertebræ. The fourth pair of lumbar arteries arise below this point.

THE VISCERAL BRANCHES OF THE ABDOMINAL AORTA.

The visceral branches of the abdominal aorta (Figs. 564 to 567 and 598) consist of three large unpaired trunks for the unpaired abdominal organs (the intestinal canal, the liver, the pancreas, and the spleen), and of three pairs of arteries for the paired abdominal organs (the kidneys, the suprarenal bodies, and the sexual glands).

(a) THE UNPAIRED BRANCHES.

I. The **cœliac artery** (Figs. 564 and 565) is a short thick trunk, a trifle over 1 cm. in length, which arises in the aortic opening from the anterior surface of the aorta, passes anteriorly at almost a right angle, and divides into its three terminal branches (the cœliac tripod of Haller). It is situated behind the lesser omentum to the right of the cardia and is distributed to the unpaired abdominal organs located above the transverse mesocolon, namely, to the stomach, the upper portion of the duodenum, the liver, the spleen and the pancreas, and to the great omentum. Its branches are:

1. The **left gastric artery**, the smallest branch, ascends in the gastropancreatic fold (see Vol. II., page 80) toward the lesser curvature of the stomach and takes up its position upon the right side of the cardia, giving off small œsophageal branches to the abdominal portion of the œsophagus, which anastomose with branches of the inferior phrenic artery and also supply the cardia. The artery then passes from the cardia to the lesser curvature of the stomach, along which it pursues a slightly tortuous course toward the pylorus. In this situation it gives off numerous branches to the anterior and the posterior walls of the stomach and to the lesser omentum, and anastomoses in the pyloric region with the right gastric artery from the hepatic artery.

II. The **hepatic artery** (Figs. 564 and 565) is a thick trunk, which is destined not only for the liver but also for the right half of the stomach and omentum, the upper portion of the duodenum, and the head of the pancreas. It runs almost transversely in front of the lumbar portion of the diaphragm and the inferior vena cava and behind the lesser curvature of the stomach. Behind the pylorus it is in relation with the portal vein and the common bile-duct, the artery being in front and to the left of the vein, and in this situation it subdivides into its terminal branches:

1. The *proper hepatic artery* (Figs. 389, 390, and 564) passes in the hepatoduodenal ligament with the portal vein and the common bile-duct to the transverse fissure of the liver, which it enters after dividing into a *left branch* and a *right branch*. The latter previously gives off

FIG. 564.—The blood-vessels of the stomach and liver.

The left and part of the right lobe of the liver have been drawn upward, the origin of the cœliac artery exposed, and the anterior lamina of the great omentum divided at the greater curvature of the stomach. * = Cut edges of great omentum.

FIG. 565.—The branches of the cœliac artery and the origin of the portal vein.

Dissection as in Fig. 564. After division of the anterior lamina of the great omentum the stomach has been drawn upward, so that its posterior surface looks forward, and the pancreas has been divided along the superior mesenteric vessels. * = Cut margin of the gastrocolic ligament at the greater curvature of the stomach; just above is the inferior portion of the duodenum. ** = Cut margin of the lesser omentum at the lesser curvature of the stomach.

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the *cystic artery* which pursues a tortuous course along the cystic duct to reach the gall-bladder.

2. The *right gastric (pyloric) artery* (Fig. 564), the smallest branch of the hepatic, is frequently given off from the proper hepatic artery. It takes a recurrent course to the pylorus, which it supplies, and anastomoses in the pyloric region with the terminal branches of the much larger left gastric artery.

3. The *gastroduodenal artery* (Figs. 564 and 565) runs almost vertically downward behind the pylorus, upon the posterior surface of which it ramifies, and divides into two terminal branches.

(*a*) The *right gastro-epiploic artery* (Figs. 564 and 565), the larger terminal, gives off small branches to the head of the pancreas and to the superior portion of the duodenum, passes to the greater curvature of the stomach, and runs toward the left in a markedly tortuous manner, parallel with the greater curvature and between the two layers of the great omentum, to anastomose with the left gastro-epiploic branch of the splenic artery. In its course it gives off branches to the anterior and posterior walls of the stomach, as well as a number (about seven) of descending branches to the great omentum, the *epiploic arteries.*

(*b*) The *superior pancreaticoduodenal artery* (Fig. 565) curves downward over the concave side of the superior and descending portions of the duodenum, giving off *duodenal branches* to these parts and *pancreatic branches* to the head of the pancreas.

III. The **splenic artery** (Figs. 393, 564, and 565) runs from its origin at the cœliac tripod almost horizontally, but in a very tortuous manner, toward the left, being situated along the upper border of the pancreas, behind the stomach, and in front of the lumbar portion of the diaphragm. In its course the artery gives off numerous small *pancreatic branches* to the body and tail of the pancreas, and divides in front of the hilus of the spleen in the gastrosplenic ligament into its terminal branches:

1. The *left gastro-epiploic artery* (Figs. 564 and 565) goes to the greater curvature of the stomach, runs in a tortuous manner from left to right between the layers of the great omentum, and forms an arched anastomosis with the right gastro-epiploic artery. Like the latter vessel, it supplies both walls of the stomach and the great omentum.

2. The *short gastric arteries* (Fig. 565) are four or five vessels of fair size, which pass to the fundus of the stomach, where they anastomose with the branches of the left gastric and left gastro-epiploic arteries.

3. The *splenic branches* (Figs. 393, 397, and 565), the actual terminals, enter the spleen through the hilus.

IV. The **superior mesenteric artery** (Figs. 393, 413, 565, 566, and 716) is somewhat

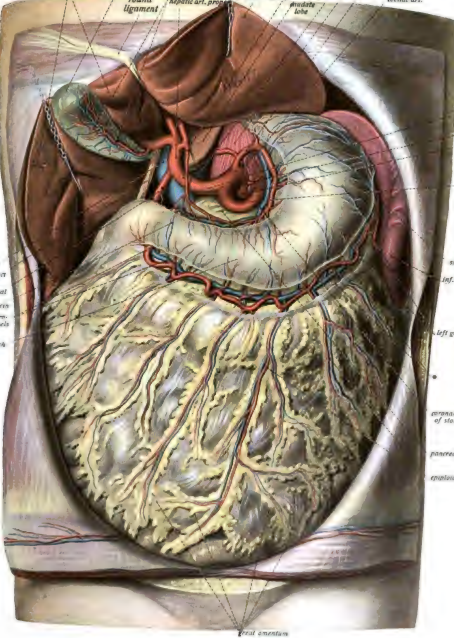
right lobe of liver
gall bladder
cystic vessels
round ligament
hepatic art. prop
left lobe
inferior vena cava
right gastric art.
caudate lobe
Diaphragm (lumbar portion)
left gastric art.
coeliac art.
[illegible]
hepatic art.
left inf. phrenic art
abdominal aorta
splenic art.
spleen
inf. extremity of spleen
left gastro-epiploic vessels
coronary vein of stomach
pancreas
epiploic vessels
portal vein
mmon bile duct
istro-duodenal art.
pyloric vein
right gastro-epiploic vessels
stomach
great omentum

Fig. 564.

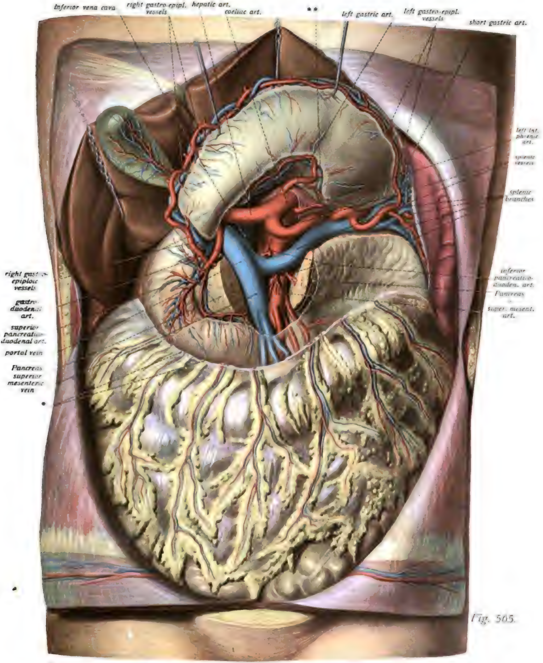
Inferior vena cava
right gastro-epipl. vessels
hepatic art.
coeliac art.
* *
left gastric art.
left gastro-epipl. vessels
short gastric art.
left inf. phrenic art.
splenic vessels
splenic branches
inferior pancreatico-duoden. art.
Pancreas
super. mesent. art.
right gastro-epiploic vessels
gastro-duodenal art.
superior pancreatico-duodenal art.
portal vein
Pancreas
superior mesenteric vein
*

Fig. 505.

smaller in caliber than the cœliac artery, but like that vessel arises from the anterior surface of the aorta. It runs downward behind the head of the pancreas, which separates it from the cœliac artery, passes in front of the inferior portion of the duodenum, and enters the root of the mesentery, in which it pursues a curved course, the convexity of which is directed forward and to the left. From this convexity are given off the intestinal arteries, while from the concavity arise the branches for the cæcum and for the ascending and transverse colons. The commencement of the artery also gives off twigs to the pancreas and to the inferior portion of the duodenum, and throughout its curved course the diminution of its caliber is constant and marked. Its branches are:

1. The *inferior pancreaticoduodenal artery* (Figs. 565 to 567) arises at the upper border of the pancreas and passes behind the head of that organ, which it supplies, to reach the inferior portion of the duodenum. It then passes upward along the concave border of the inferior and descending portions of the duodenum, to which it gives branches, and forms an arch-like anastomosis with the superior pancreaticoduodenal artery.

2. The *intestinal arteries* (Figs. 566 and 567) are rather large trunks, usually ten to fifteen in number, which arise from the entire length of the convexity of the superior mesenteric (consequently from its left side). The upper ones supply the jejunum as the *jejunal arteries*, while the lower nourish the ileum as the *ileal arteries*, the lowermost of which arise from the termination of the superior mesenteric. Soon after its origin each intestinal artery divides into two diverging branches, which anastomose in the mesentery with the corresponding branches of the neighboring arteries, so that a series of arches is produced. These arches give off smaller arterial branches, which act in a similar manner, and this condition repeats itself until there are three or four irregular arched anastomoses in the mesentery, the last of which is situated close to the mesenteric attachment. From this last series of arches are given off the twigs for the wall of the small intestine. The terminal ramifications of the superior mesenteric artery anastomose with the lowermost intestinal artery, and also with the left branch of the ileocolic artery, at the lower extremity of the ileum.

3. The *middle colic artery* (Figs. 566 and 567) arises opposite the upper intestinal arteries from the concave side of the upper portion of the superior mesenteric, and runs in the right portion of the transverse mesocolon to the region of the right colic flexure, where it divides into a long superior branch and a smaller descending branch. The long superior branch passes to the left along the mesenteric attachment of the transverse colon and forms an arched anastomosis* with the left colic artery from the inferior mesenteric; the smaller descending branch passes downward and to the right behind the ascending mesocolon to the ascending colon, at the inner side of which it anastomoses with the ascending branch of the right colic artery.

4. The *right colic artery* (Fig. 566) arises at about the middle of the superior mesenteric from the left concave side of the arch, passes almost horizontally to the right behind the ascending mesocolon, and divides into an ascending and a descending branch. At the upper portion of the ascending colon the ascending branch anastomoses with the middle colic artery; at the upper portion of the cæcum the descending branch anastomoses with the ileocolic artery.

* The arteries for the colon, in contrast to those for the small intestine, form only a single typical but large arterial arch in the vicinity of the intestinal tube and from this arch are given off the arteries for the intestinal wall. These arteries, however, are connected by a number of irregular anastomoses before they enter the wall of the colon.

FIG. 566.—The superior mesenteric artery and vein.

The transverse colon with the great omentum has been thrown upward, the intestinal coils displaced to the left, and the ascending mesocolon, part of the transverse mesocolon, and the right layer of the mesentery removed. * = Cut margin of transverse mesocolon.

FIG. 567.—The inferior mesenteric artery and vein.

Dissection as in Fig. 566. The intestinal coils have been displaced to the right and the branches of the inferior mesenteric vessels shown by removing parts of the pancreas and transverse mesocolon. * = Aortic bifurcation. ** = Cut margins of transverse mesocolon. + Promontory of sacrum. * + Inferior pancreaticoduodenal artery (the branches passing to the pancreas have been cut away).

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5. The *ileocolic artery* (Fig. 566) arises from the lower third of the left or concave side of the superior mesenteric artery, and passes downward and to the right behind the ascending mesocolon to reach the ileocæcal region, where it divides into two branches. The upper and larger branch supplies the cæcum and anastomoses with the right colic artery, while the lower and smaller branch passes to the terminal portion of the ileum, where it anastomoses with the terminal ramifications of the trunk of the superior mesenteric artery.

V. The **inferior mesenteric artery** (Figs. 413, 567, 568, and 716) arises from the left side of the anterior surface of the aorta, about midway between the origin of the superior mesenteric artery and the aortic bifurcation. It runs downward and to the left behind the descending mesocolon, and gives off the following branches:

1. The *left colic artery* (Fig. 567) divides behind the descending mesocolon into an ascending branch and one or more descending branches. The ascending branch anastomoses at the transverse colon with the middle colic artery from the superior mesenteric; the descending branches go to the lower portion of the descending colon and anastomose with the upper sigmoid arteries.

2. The *sigmoid arteries* (Fig. 567) are several branches which pass to the sigmoid colon and form arched anastomoses with each other. The upper sigmoid arteries anastomose with the left colic artery in the same manner.

3. The *superior hemorrhoidal artery* (Figs. 567, 569, and 570), the largest artery of the rectum, is the actual terminal branch of the inferior mesenteric artery. It runs at the left side of the promontory and in front of the pelvic surface of the sacrum to the rectum, in the wall of which it ramifies from the posterior and left portion of its circumference. It supplies the entire upper and middle portions of the rectum and partly supplies the lower portion, where it anastomoses with the middle hemorrhoidal artery.

(b) THE PAIRED BRANCHES.

1. The *right* and *left middle suprarenal arteries* (Figs. 474 and 716) are small twigs, usually arising independently from the abdominal aorta. They assist in the nourishment of the suprarenal bodies, which are also supplied by the superior (see page 59) and the inferior (see page 59) suprarenal arteries.

2. The *right* and *left renal arteries* (Figs. 413 and 716) are much larger than the preceding vessels. They arise at almost a right angle from the lateral surfaces of the aorta below the superior mesenteric artery, their caliber being about the same as that of this vessel. The right renal artery is somewhat longer than the left, frequently arises at a somewhat lower level, and passes

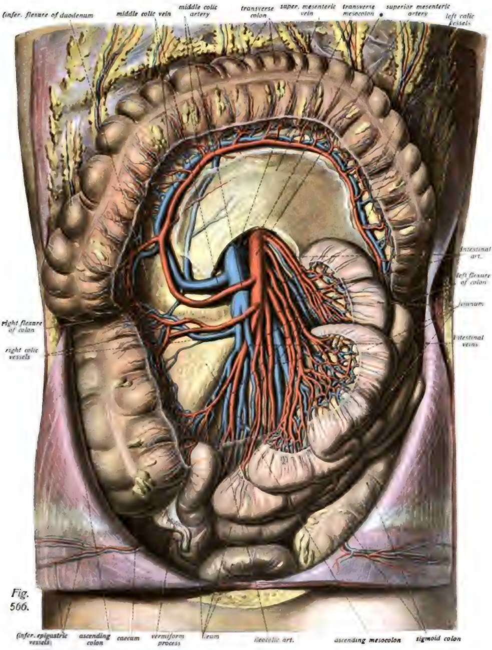

(infer. flexure of duodenum
middle colic vein
middle colic artery
transverse colon
super. mesenteric vein
transverse mesocolon
superior mesenteric artery
left colic vessels
intestinal art.
left flexure of colon
jejunum
intestinal veins
right flexure of colon
right colic vessels
(infer. epigastric vessels)
ascending colon
caecum
vermiform process
ileum
ileocolic art.
ascending mesocolon
sigmoid colon

Fig. 566.

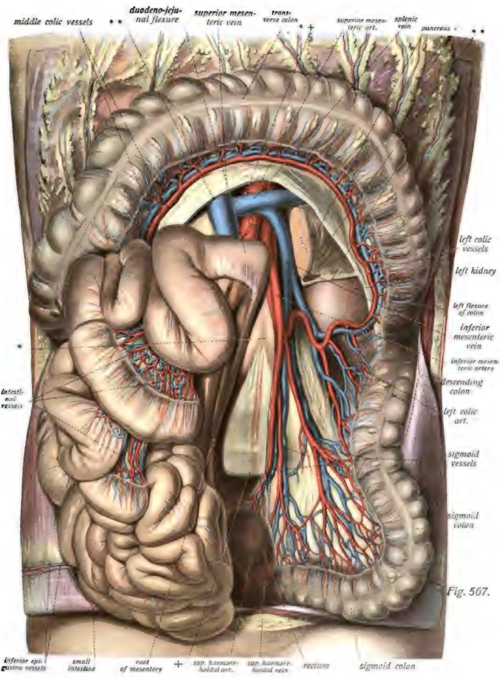

middle colic vessels
* *
duodeno-jejunal flexure
superior mesenteric vein
transverse colon
* +
superior mesenteric art.
splenic vein
pancreas
* *
left colic vessels
left kidney
left flexure of colon
inferior mesenteric vein
inferior mesenteric artery
descending colon
left colic art.
sigmoid vessels
sigmoid colon
*
Intestinal vessels
inferior epigastric vessels
small intestine
root of mesentery
+
sup. haemorrhoidal art.
sup. haemorrhoidal vein
rectum
sigmoid colon

Fig. 567.

behind the inferior vena cava to reach the hilus of the kidney. Before entering the hilus each artery gives off a branch to the suprarenal body, the *inferior suprarenal arteries*, and as it enters the hilus breaks up into several branches.

[The majority of these branches enter the renal sinus anterior to the pelvis and supply that portion of the kidney substance which lies anterior to the median sagittal plane of the organ, that portion forming its lateral border, so much of that forming the posterior half as lies lateral to the line of the posterior row of calyces—in other words, a little more than half the total amount of the kidney substance. The remainder is supplied by the branches which pass posterior to the pelvis. Between the anterior and posterior branches no anastomoses occur and, consequently, the plane of the posterior row of calyces marks a region where only the finest terminal branches of the arteries will be found, so that incision of the kidney substance in this plane, sometimes known as the "bloodless area" of the kidney, will be accompanied by a minimum of hemorrhage.—ED.]

3. The *right* and *left internal spermatic arteries* (Figs. 413, 570, and 716) are long slender vessels which arise in close proximity to each other from the lateral portions of the anterior surface of the aorta, below the renal artery, but above the inferior mesenteric. They leave the aorta at a very acute angle and run downward upon the psoas major (or minor), behind the parietal peritoneum and in front of the ureter, which they cross at an acute angle, giving off no actual branches and pursuing a slightly tortuous course toward the true pelvis. The right artery is situated in front of the inferior vena cava.

Beyond this point the internal spermatic arteries vary in the two sexes and are consequently known by different names. In the male it is called the testicular artery, since it goes to the testicle, in the female the ovarian artery, because it is the main artery of the ovary.

In the male the *testicular artery* (Figs. 413, 490, 571, and 716) does not enter the true pelvis, but passes along its margin in front of the external iliac vessels and enters the inguinal canal. Thence, surrounded by the veins of the pampiniform plexus (see page 99) it passes downward in the spermatic cord to the testicle, in the substance of which it gives off several branches which ramify from the mediastinum testis and anastomose freely with each other. It also supplies the epididymis.

In the female the *ovarian artery* (Figs. 570 and 572) enters the true pelvis on the medial side of the psoas major. It is usually markedly tortuous, and runs in the suspensory ligament to the ovary, the hilus of which it enters after breaking up into several branches and anastomosing with the ovarian branch of the uterine artery. Small twigs also pass to the ampulla of the tuba uterina in the vicinity of the infundibulum.

THE PARIETAL BRANCHES OF THE ABDOMINAL AORTA.

In contrast with the visceral branches the parietal branches of the abdominal aorta (Fig. 716) play a minor rôle. Some of them (the inferior phrenic arteries) ramify in the diaphragm, while others (the lumbar arteries) pursue a course analogous to that of the intercostal arteries. They are all paired.

1. The *right* and *left inferior phrenic arteries* (Figs. 564, 565, and 716) arise in the aortic opening, but below the cœliac artery, in a somewhat variable manner, either separately or by a common stem from the aorta, or one or the other occasionally from the cœliac artery. Before each artery passes to the diaphragm it usually gives one or more branches to the suprarenal bodies, the *superior suprarenal arteries*. It then ramifies upon the lower surface of the lumbar

portion of the contiguous costal portion of the diaphragm and is considerably larger than the superior phrenic artery. Both arteries anastomose with each other and with the remaining arteries supplying the diaphragm, the pericardiacophrenic and musculophrenic arteries, and also with the lower intercostal and the upper lumbar arteries. The right inferior phrenic artery passes behind the inferior vena cava and sends small twigs to this structure and to the falciform ligament of the liver; the left artery passes behind the cardia of the stomach.

2. The *right* and *left lumbar arteries* (Fig. 716) are four pairs of arteries which arise in two rows from the posterior surface of the aorta. They run at right angles to the aorta in a curve, the convexity of which is anterior, over the lateral surfaces of the bodies of the lumbar vertebræ, the right arteries passing behind the inferior vena cava, and the uppermost pair being largely covered by the lumbar portion of the diaphragm. Passing over the upper part of the bodies of the four upper lumbar vertebræ, the arteries pass behind the tendinous arches of the psoas major and divide within this muscle into an anterior branch and a posterior branch, like the intercostal arteries. The *posterior branch* sends a *spinal branch* through the intervertebral foramen to the dura mater and to the cauda equina, and supplies the lower portion of the sacrospinalis and the skin of the lumbar region. The *anterior branch* supplies the psoas and quadratus lumborum, runs between the fibers of the latter muscle, and terminates in the posterior portions of the flat abdominal muscles. The lumbar arteries form numerous anastomoses, as, for example, with the intercostal arteries (especially the upper lumbar arteries), with the iliolumbar artery (especially the fourth lumbar artery, running along the upper margin of the crest of the ilium), and also with the gluteal arteries in the glutæus maximus, to which some of the branches may extend.

Not infrequently variations occur in the order in which the branches arise from the abdominal aorta. The cœliac and the superior mesenteric arteries may arise from a common trunk; one of the internal spermatic arteries may take origin from the renal artery, and the renal artery is frequently double upon one or both sides or an accessory renal may be present. Such abnormal renal arteries may replace the normal vessel and may arise from the common iliac artery or from the aortic bifurcation, the latter origin being especially common in abnormal situations of the kidney. In rare instances an accessory hepatic artery is derived from the superior mesenteric artery, and less important anomalies of the suprarenal and inferior phrenic arteries are frequent and have in part been already mentioned.

THE MIDDLE SACRAL ARTERY.

Although of but moderate size, the middle sacral artery (Figs. 568 and 716) in its direction is the immediate continuation of the abdominal aorta, and cannot be regarded as one of its branches. The artery arises at the aortic bifurcation (see page 54) as a single vessel and passes downward exactly in the median line over the anterior surface of the body of the fifth lumbar vertebra and over the pelvic surface of the sacrum to the tip of the coccyx, where it terminates in the so-called coccygeal glomus, a conglomeration of vessels about 2 mm. in diameter, which is imbedded in the pelvic fatty tissue.

In front of the middle of the body of the fifth lumbar vertebra the middle sacral artery gives off the fifth pair of lumbar arteries, the *lowest lumbar arteries*, which are distributed like the four upper pairs, although of smaller size; they run behind the psoas and anastomose upon the iliacus with the branches of the iliolumbar artery. Upon the pelvic surface of the sacrum the middle sacral artery gives off transverse branches which anastomose with the lateral sacral arteries, and supply the sacrum and part of the origins of the piriformis, coccygeus, and levator ani.

THE COMMON ILIAC ARTERY.

In addition to the middle sacral artery, the *right* and *left common iliac arteries* (Figs. 569, 570, 715, and 716) arise at the site of the bifurcation of the abdominal aorta, in front of the fourth lumbar vertebra, and from their caliber would seem to be the immediate continuations of the aorta. They are short, almost straight unbranched trunks, whose terminals supply the pelvic region and the lower extremity. The common iliac arteries leave the aorta at an angle of 65 to 75 degrees and are from 5 to 6 cm. in length. Each runs obliquely across the lower portions of the fourth and fifth lumbar vertebræ, then along the boundary between the true and the false pelvis at the inner margin of the psoas major to the vicinity of the sacro-iliac articulation, where it divides into its terminals—the hypogastric and the external iliac arteries.

The right common artery is anterior and medial to the origin of the inferior vena cava, in front of the terminal portion of the left common iliac vein, and medial and somewhat anterior to its own accompanying vein (the right common iliac vein). The left artery is lateral to its vein. In front of the common iliac arteries are the parietal peritoneum and the ureter; upon the left side there is also the inferior mesenteric or the superior hemorrhoidal artery, and upon the right the lower portion of the root of the mesentery. With the exception of the terminal branches, the common iliac arteries give off only small twigs to neighboring structures (veins, lymphatic nodes).

The hypogastric artery supplies the walls of the true pelvis, the pelvic viscera, the pelvic floor, the perineum, and the gluteal region, while the external iliac artery continues the direction of the common iliac and passes downward as the main blood-vessel of the lower extremity.

THE HYPOGASTRIC ARTERY.

The *hypogastric* (*internal iliac*) *artery* (Figs. 568, 569, 715, and 716) arises from the common iliac in the vicinity of the sacro-iliac articulation, and passes medially and somewhat backward around the medial border of the psoas major to enter the true pelvis, where it soon divides into numerous branches in a very inconstant manner. The *visceral branches* pass to the organs of the true pelvis (the rectum, the urinary bladder, and in the female the uterus and the tubæ), to the perineum, and to the external genitalia; the *parietal branches* supply the pelvic walls, the buttock, and a portion of the thigh. Usually the artery divides into an anterior and a posterior division. The anterior division gives off the visceral branches and usually the obturator artery, and terminates as the inferior gluteal and the pudendal arteries or as the latter vessel alone. The posterior division, usually the larger, gives off the majority of the parietal branches, and terminates as the superior gluteal artery or as the superior and the inferior gluteals.

THE PARIETAL BRANCHES.

1. The *iliolumbar artery* (Figs. 568 and 716) arises from the posterior surface of the hypogastric, usually before this vessel has separated into its two divisions. It passes upward, backward, and outward behind the psoas major to reach the iliac fossa, where it divides into an *iliac* and a *lumbar branch*. The latter anastomoses with the fourth and lowest lumbar arteries and ramifies exactly like the posterior branches of the lumbar arteries. The larger iliac branch

FIG. 568.—The blood-vessels and nerves on the right pelvic wall.

The pelvis has been halved by a sagittal section and the genitalia removed. * = Branches to the coccygeus. ** = Branch to levator ani. + = Site of abdominal inguinal ring. + + = Branches to piriformis.

FIG. 569.—The vessels of the male genitalia (profile view).

The left half of the pelvis has been removed by a section passing from the median line behind to one side of the median line anteriorly; the vessels coming from the left side to the rectum and genitalia have consequently been divided. The peritoneum has been removed, excepting that portion which lines the anterior surface of the abdominal wall. *x* = Left ureter divided just before entering the bladder. *xx* = Left vas deferens.

runs transversely across the iliacus, gives branches to this muscle, and anastomoses with the deep circumflex iliac artery from the external iliac.

2. The *lateral sacral artery* or *arteries* (Fig. 568) usually consist of a superior and an inferior artery which run downward on the lateral portion of the pelvic surface of the sacrum, in front of the origin of the piriformis and the anterior divisions of the sacral nerves, sending branches to these structures and anastomosing with the middle sacral artery. They give off *spinal branches* which pass through the anterior sacral foramina to the sacral canal, leave the sacral canal through the posterior sacral foramina, and supply the dorsal surface of the sacrum together with the ligaments and muscles found in this locality.

3. The *obturator artery* (Figs. 568, 569, 574, and 575) runs near the upper margin of the true pelvis (the terminal line and the psoas major), giving off small branches to the lateral pelvic wall and passing forward toward the superior pubic ramus, to the posterior surface of which it sends the *pubic branch*, which anastomoses in the vicinity of the lacunar ligament with the pubic branch of the inferior epigastric artery. This anastomosis may be responsible for an abnormal origin of the obturator artery. In about 30 per cent. of all cases the artery, instead of coming from the hypogastric, arises from the inferior epigastric artery by means of a large trunk which arches over the lacunar ligament into the true pelvis. After giving off the pubic branch the obturator artery enters the obturator groove and canal, sends branches to the obturator internus and externus, and, upon leaving the canal, divides into an anterior and a posterior branch. The *anterior branch* supplies chiefly the adductor brevis and the adductor longus. The *posterior branch* sends the small *acetabular artery* through the acetabular notch to the hip-joint and to the round ligament, and ramifies chiefly in the posterior adductors, its terminal branches extending to the gemelli and the quadratus femoris. The posterior branch anastomoses freely with the inferior gluteal artery, but especially with the internal circumflex artery from the femoral.

4. The *superior gluteal artery* (Figs. 568, 577, and 717), one of the large terminal branches of the hypogastric, passes between the roots of the sacral plexus, through the great sacrosciatic foramen above the piriformis, and reaches the gluteal region where it is covered by the glutæus maximus and partly also by the glutæus medius. In this situation it divides into two branches, which are termed the *superior* and the *inferior* branches, and which supply the glutæus medius, the glutæus minimus, and also the upper portion of the glutæus maximus. The principal ramification of the artery takes place between the glutæus medius and minimus, and the branches extend from this situation to the piriformis on the one hand, and to the trochanteric rete on the other, and anastomose with the inferior gluteal artery, the circumflex branches of the femoral, and also partly with the lumbar and iliolumbar arteries.

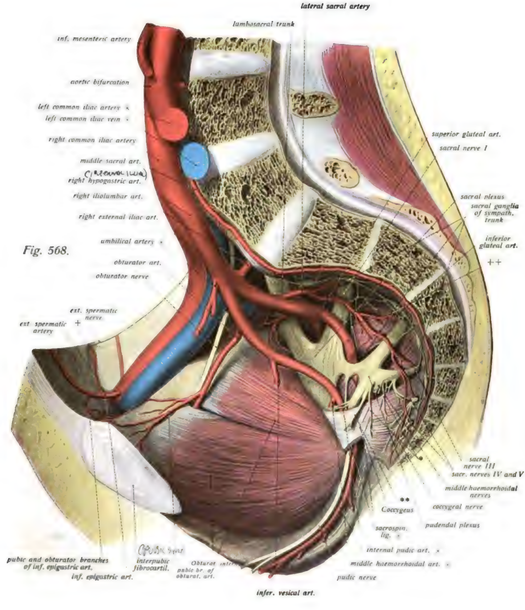
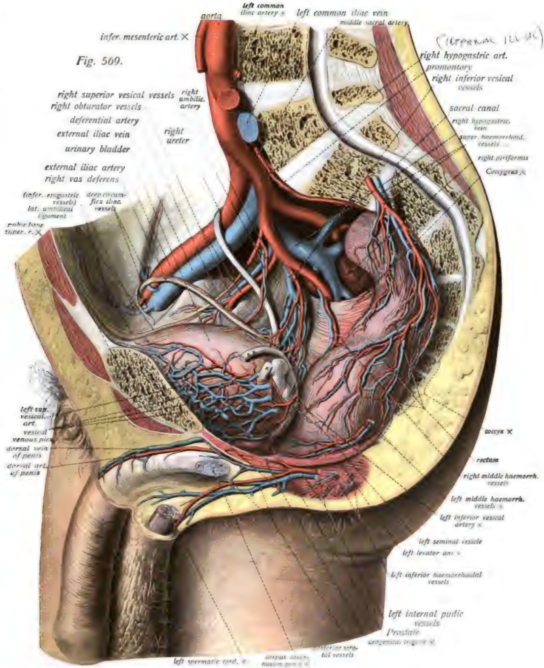

lateral sacral artery
lumbosacral trunk
inf. mesenteric artery
aortic bifurcation
left common iliac artery ×
left common iliac vein •
right common iliac artery
middle sacral art.
(INTERNAL ILIAC)
right hypogastric art.
right iliolumbar art.
right external iliac art.
umbilical artery •
obturator art.
obturator nerve
ext. spermatic nerve
ext. spermatic artery +
superior gluteal art.
sacral nerve I
sacral plexus
sacral ganglia of sympath. trunk
inferior gluteal art.
++
sacral nerve III
sacr. nerves IV and V
middle haemorrhoidal nerves
coccygeal nerve
••
Coccygeus
pudendal plexus
sacrospin. lig. •
internal pudic art. ×
middle haemorrhoidal art. •
pudic nerve
(PUBIC SYMP
pubic and obturator branches of inf. epigastric art.
interpubic fibrocartil.
Obturat. intern.
pubic br. of obturat. art.
inf. epigastric art.
infer. vesical art.

Fig. 568.

Fig. 569.


left common iliac artery ×
left common iliac vein
aorta
middle sacral artery
infer. mesenteric art. ×
(Internal iliac)
right hypogastric art.
promontory
right inferior vesical vessels
right superior vesical vessels
right umbilic. artery
right obturator vessels
deferential artery
external iliac vein
right ureter
urinary bladder
sacral canal
right hypogastric. vein
super. haemorrhoid. vessels
right piriformis
Coccygeus ×
external iliac artery
right vas deferens
(infer. epigastric vessels)
lat. umbilical ligament
deep circumflex iliac vessels
pubic bone super. r. ×
left sup. vesical. art.
vesical venous plex.
dorsal vein of penis
dorsal art. of penis
coccyx ×
rectum
right middle haemorrh. vessels
left middle haemorrh. vessels ×
left inferior vesical artery ×
left seminal vesicle
left levator ani ×
left inferior haemorrhoidal vessels
left internal pudic vessels
Prostate
urogenital trigone ×
posterior scrotal vessels
corpus cavernosum penis ×
left spermatic cord. ×

5. The *inferior gluteal* (*sciatic*) *artery* (Figs. 577, 717, and 724), also one of the terminal branches of the hypogastric, likewise passes through the great sacrosciatic foramen, but below the piriformis, to reach the gluteal region, where it is covered only by the glutæus maximus. It ramifies in the lower portion of the glutæus maximus, the obturator internus, the gemelli, and the quadratus femoris, forms the trochanteric rete, anastomoses with the superior gluteal artery, with the posterior branch of the obturator artery, with the circumflex branches of the femoral artery, and, if it extends downward as far as the adductor minimus, also with the first perforating artery. It sends one or two slender, markedly tortuous branches downward along the sciatic nerve, the *arteria comitans nervi ischiadici*.

THE VISCERAL BRANCHES.

The visceral branches of the hypogastric artery differ in the two sexes, since in the female there is a large branch, the uterine artery, to which the homologue in the male, the deferential artery, corresponds neither in its origin nor caliber. The ramifications of the internal pudendal artery also exhibit certain differences in the two sexes.

1. The *umbilical artery* (Figs. 568 to 570) is before birth not only the most important branch of the hypogastric, but is actually the immediate continuation of the common iliac artery; at first it is even the immediate continuation of the aorta (see Fig. 598). After birth the greater portion of the artery, that extending from the vertex of the bladder to the umbilicus, becomes obliterated and forms the lateral umbilical ligament, while the portion between the hypogastric artery and the bladder remains pervious in the adult, although it is only of moderate caliber, and gives off the superior vesical arteries which ramify in the region of the vertex of the bladder and in the middle umbilical ligament.

2. The *inferior vesical artery* (Figs. 568 to 570) arises from the anterior division of the hypogastric, above the pelvic floor, and passes to the base of the bladder; it also supplies in the male the prostate and the seminal vesicles, and in the female the urethra and the vagina. In the male it gives origin to the small *deferential artery*, which accompanies the vas deferens, enters the spermatic cord, and anastomoses in the scrotum with the testicular artery.

3. The *uterine artery* (Figs. 570 and 572) passes to the lateral surface of the supravaginal portion of the cervix uteri, sends a descending *vaginal artery* to the vagina, and then pursues a markedly tortuous course along the insertion of the broad ligament into the uterus, passing upward along the lateral surface of the cervix and body of the uterus and sending numerous branches to the muscular wall of the uterus and through this to the mucous membrane. In addition to branches to the broad ligament it also sends an *ovarian branch* along the ovarian ligament to the ovary, to anastomose in this situation with the ovarian artery, and a *tubal branch*, which runs in the mesosalpinx to the tuba uterina, the greater portion of which it supplies. This tubal branch gives off a slender twig which accompanies the round ligament of the uterus to the inguinal ring.

4. The *middle hemorrhoidal artery* (Figs. 568 to 570) arises immediately above the sacrospinous ligament from the trunk of the hypogastric artery (occasionally from the anterior division), and passes immediately above the pelvic diaphragm to the rectum and the levator ani. In the male it also supplies the seminal vesicles and the prostate and in the female the vagina. At

FIG. 570.—The vessels of the female genitalia as seen from the left side.

Dissection as in Fig. 569. The left ovary and tube have been drawn forward and downward, the right ovary and tube upward. * = Vaginal branches of inferior vesical artery.

FIG. 571.—The vessels and nerves of the penis, spermatic cord, and scrotum as seen from in front.

The skin and the greater portion of the fascia have been removed from the penis; the vessels of the right spermatic cord have been exposed by dividing its coverings.

FIG. 572.—The arteries of the female internal genitalia as seen from behind.

The lower portion of the broad ligament has been removed, the left ovarian ligament divided, and the peritoneum of the mesosalpinx removed along the vessels.

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the rectum it anastomoses with the superior hemorrhoidal artery from the inferior mesenteric and with the inferior hemorrhoidal arteries (see below). It is also connected with other visceral branches of the hypogastric artery (the uterine and the inferior vesical arteries).

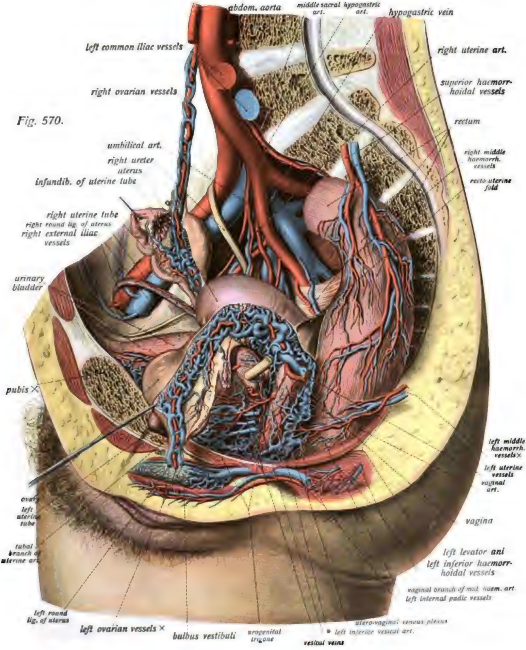
5. The *internal pudendal artery* (Figs. 568 to 571, 724, and 725) is not a pure visceral branch, inasmuch as it also supplies the perineum and the region of the anus. It is, however, the chief artery for the external genitalia. It is almost always the termination of the anterior division of the hypogastric artery, and passes to the gluteal region with the inferior gluteal artery by passing through the great sacrosciatic foramen below the piriformis. It leaves the gluteal region through the lesser sacrosciatic foramen, winding around the posterior surface of the sacrospinous ligament, and enters the ischiorectal fossa. At the outer margin of this fossa, close to the tuberosity and the inferior ramus of the ischium and above the falciform process of the sacrotuberous ligament, the artery passes forward and inward toward the perineum and the external genitalia. It is covered by the obturator fascia and is situated close to the origin of the levator ani from this fascia. The branches of the internal pudendal artery are:

(*a*) The *inferior hemorrhoidal artery* or *arteries* (Figs. 724 and 725), usually several branches arising by a common trunk, pass downward and inward through the ischiorectal fat to the anus and supply the musculature (the levator and sphincter ani) and the integument of the anus, as well as the anal portion of the rectum in general. They anastomose with the middle hemorrhoidal artery from the hypogastric.

(*b*) The *perineal artery* (Figs. 724 and 725) passes toward the median line of the perineum, parallel with the superficial transversus perinei, giving off small branches, ramifying in the musculature and integument, and terminating in the *posterior scrotal* (*labial*) *arteries*, which represent the superficial terminal branches of the internal pudendal artery. Each perineal artery is at first covered by the superficial transversus perinei, and then passes in the groove between the bulbocavernosus and the ischiocavernosus with the nerves of the same name to the posterior portion of the scrotum in the male and to the posterior segments of the labia majora in the female.

(*c*) The *artery of the penis* in the male (Fig. 724) or the *artery of the clitoris* in the female (Fig. 725) is the actual deep terminal branch of the internal pudendal artery, and is naturally of much larger size in the male than in the female. It continues in the direction of its parent trunk, running forward and inward through the outer portion of the urogenital trigone to the lower aspect of the symphysis pubis, where it passes between this structure and the transverse ligament of the pelvis and divides into its terminal branches, the *dorsal artery of the penis* (*clitoris*) and the *deep artery of the penis* (*clitoris*). The branches of the artery of the penis are:

Fig. 570.


abdom. aorta
middle sacral art.
hypogastric art.
hypogastric vein
left common iliac vessels
right uterine art.
superior haemorrhoidal vessels
right ovarian vessels
rectum
umbilical art.
right ureter
uterus
infundib. of uterine tube
right middle haemorrh. vessels
recto uterine fold
right uterine tube
right round lig. of uterus
right external iliac vessels
urinary bladder
pubis ×
left middle haemorrh. vessels×
left uterine vessels
vaginal art.
ovar
left
uterin
tube
vagina
tubal
branch o
uterine art
left levator ani
left inferior haemorrhoidal vessels
vaginal branch of mid. haem. art.
left internal pudic vessels
left round lig. of uterus
left ovarian vessels ×
bulbus vestibuli
urogenital trigone
utero-vaginal venous plexus
* left inferior vesical art.
vesical veins

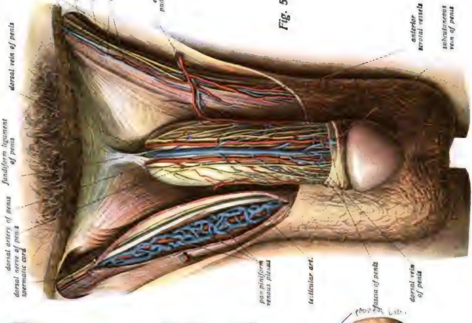


Fig. 571.

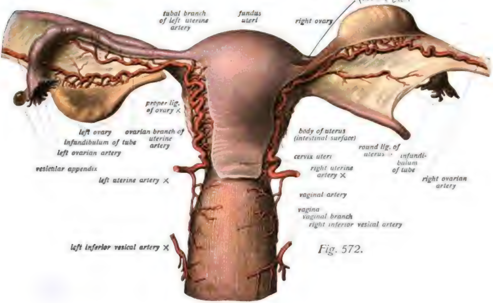


Fig. 572.

(*α*) The *urethral artery* is the largest of a number of small twigs which pass to the membranous portion of the urethra and to the deep transversus perinei.

(*β*) The *artery of the bulb of the urethra* supplies the bulb and the body of the corpus cavernosum urethræ and the urethra itself.

(*γ*) The *dorsal artery of the penis*, one of the terminal branches and a paired vessel, accompanies the single dorsal vein to the dorsum of the male organ, where it is covered by the fascia of the penis, and passes anteriorly in a slightly tortuous manner to reach the corona of the glans, where it breaks up into numerous branches. In its course it gives off twigs not only to the skin but also to the glans penis and to the corpora cavernosa, these latter piercing the albuginea and anastomosing with the branches of the deep artery of the penis.

(*δ*) The *deep artery of the penis* penetrates the corpus cavernosum from the medial side, and runs forward in this structure near the septum penis, anastomosing with its fellow of the opposite side by twigs which pierce the septum.

In the female the *artery of the clitoris* pursues a course analogous to that of the artery of the penis in the male, but the vessel is correspondingly smaller. Instead of an artery of the urethral bulb it gives off an *artery of the vestibular bulb*, and divides into the *dorsal artery of the clitoris* and the *deep artery of the clitoris*. The latter vessel is very small.

Slight deviations in the ramification of the hypogastric artery are very common. Neighboring arteries frequently arise from a common trunk, and the lower visceral branches (the inferior vesical and the middle hemorrhoidal arteries) frequently originate from the internal pudendal artery. The greatest number of anomalies, however, are exhibited by the obturator artery. The most frequent of these is the origin of the obturator from the inferior epigastric or by means of this vessel from the external iliac artery, as has previously been mentioned (see page 62). It may also arise from the common iliac artery (rare) or from the femoral artery (very rare). But even when it has an anomalous origin, there is almost always present a small normal artery coming from the hypogastric and joining the large abnormal vessel in the obturator canal.

THE EXTERNAL ILIAC ARTERY.

The external iliac artery (Figs. 568 to 570, 573, 574, 716) continues in the direction pursued by the common iliac artery and extends from its origin from this vessel to the inguinal ligament, beyond which it is known as the femoral artery. It runs from above downward, from behind forward, and from within outward, along the inner margin of the psoas to the lacuna vasorum, where it is situated lateral to the femoral vein and upon the iliopectineal fascia. The course of the vessel is slightly curved, the convexity being directed backward and outward; it is separated from the psoas muscle and the femoral nerve by the iliac fascia and is crossed in the male by the internal spermatic vessels. Only very small twigs are given off to the surrounding structures until just before the artery enters the lacuna vasorum, when it gives origin to two larger branches. These are:

1. The *inferior epigastric artery* (Figs. 568, 569, 570, and 716) arises at the level of the inguinal ligament from the medial surface of the external iliac. It runs at first almost horizontally toward the median line for a short distance, this portion of the vessel being situated behind the inguinal and lacunar ligaments and crossed by the vas [illegible]. It then curves upward and outward,

FIG. 573.—The vessels and nerves of the anterior surface of the thigh (superficial layer). Only the fascia has been removed. * = Branch of femoral nerve to pectineus.

FIG. 574.—The vessels and nerves of the anterior surface of the thigh (middle layer). The sartorius and pectineus have been divided. * = Branch of obturator artery to hip-joint.

reaches the outer margin of the rectus abdominis above the pubic symphysis, forming the epigastric fold (see Vol. II., p. 80), pierces the transversalis fascia, and runs upward upon the posterior surface of the rectus abdominis. Above the semicircular line the artery passes to the anterior surface of the posterior layer of the sheath of the rectus, and then penetrates the rectus, in which it ramifies and anastomoses freely with the terminal branches of the superior epigastric artery from the internal mammary artery. In this manner there occurs in the substance of the rectus abdominis an anastomosis between the artery of the upper and that of the lower extremity. In addition to the ramification in the rectus, the inferior epigastric artery also gives off a number of smaller branches:

(*a*) The ***pubic branch*** is a small twig which comes from the first part of the artery, runs upon the lacunar ligament to the posterior surface of the superior pubic ramus, and at the symphysis anastomoses with its fellow of the opposite side and, by means of its ***obturator branch***, also with the pubic branch of the obturator artery.

(*b*) The ***external spermatic (cremasteric) artery*** (Figs. 568 and 571) arises at about the same level as the pubic branch, and, in the male, passes through the inguinal canal to the spermatic cord and its coverings, particularly supplying the cremaster muscle and anastomosing with the testicular artery. In the female the vessel is much smaller and is known as the ***artery of the round ligament.***

2. The ***deep circumflex iliac artery*** (Figs. 573 and 574) arises almost exactly opposite to the inferior epigastric from the lateral surface of the external iliac. It is covered by the iliac fascia, and runs upward and outward, parallel with the inguinal ligament, to the anterior superior spine of the ilium, and then curves along the iliac crest between the internal lip and the origin of the iliacus, anastomosing with the iliac branch of the iliolumbar artery. In addition to branches to the iliacus, the deep circumflex iliac artery also sends branches to the neighboring portions of the flat abdominal muscles and partly also to the proximal portion of the thigh.

THE FEMORAL ARTERY.

The ***femoral artery*** (Figs. 573 and 574) is the immediate continuation of the external iliac artery and extends from the inguinal ligament to the adductor opening in the adductor magnus. After passing through this orifice it is known as the ***popliteal artery***, so that the external iliac, the femoral, and the popliteal arteries are really one and the same vessel, different names being applied to it in different regions, just as was the case with the artery of the upper extremity (the subclavian, the axillary, and the brachial arteries).

The position of the femoral artery is accurately determined throughout its entire length by the muscles of the thigh. At first it is situated beneath the inguinal ligament in the iliopectineal fossa, between the two muscles which bound this space and lateral to the accompanying femoral

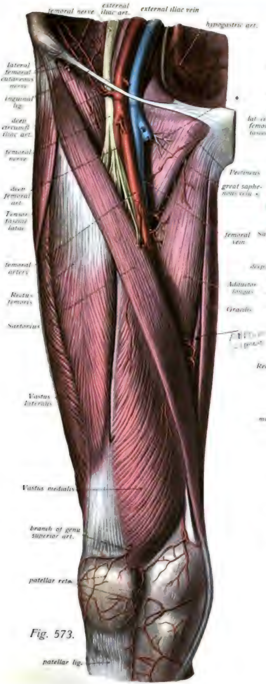


Fig. 573.

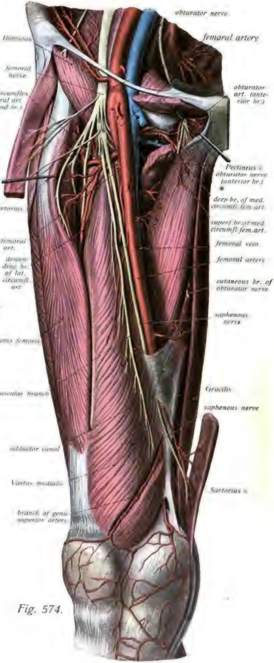


Fig. 574.

vein. Lateral to the artery is the femoral nerve, with the beginning of its ramification. The artery is covered by the superficial layer of the fascia lata in such a manner that it is usually partly within the region of the fossa ovalis, and the large subinguinal lymphatic nodes are also usually immediately in front of it. The deep layer of the fascia lata (the pectineal fascia) forms the sheath for the femoral vessels, passing behind them to join with the iliac fascia to form the iliopectineal fascia.

Below the iliopectineal fossa the femoral artery is situated in the femoral trigone formed by the sartorius and the adductor longus; at the apex of the triangle the artery passes behind the inner border of the sartorius and enters the adductor canal between the origin of the vastus medialis and the insertions of the adductors, where it is surrounded by tendinous portions of the fascia lata. The femoral vein which lay medial to it in the iliopectineal fossa now takes a position behind the artery, and with this relation the artery reaches the adductor opening.

The course of the femoral artery is usually straight and almost vertical, although it may rarely be slightly tortuous. The chief branches are given off in the iliopectineal fossa and the artery then diminishes markedly in caliber; the actual artery of the thigh, the deep femoral, is also given off in this situation.

In addition to the deep femoral artery, a number of small cutaneous branches arise in the iliopectineal fossa, and pierce the fascia lata in the vicinity of the fossa ovalis. These are:

1. The *inguinal branches*, which supply the integument and the lymphatic nodes of the subinguinal region.

2. The *superficial epigastric artery* (Fig. 600) passes upward in front of the fascia lata and the inguinal ligament to the skin of the abdomen.

3. The *superficial circumflex iliac artery* (Fig. 600) may arise in common with the preceding vessel. It pierces the fascia lata near the fossa ovalis and runs parallel with the inguinal ligament to the anterior superior spine of the ilium, where it ramifies in the integument.

4. The *external pudendal arteries* (Figs. 571 and 600) are usually two small vessels which pass transversely inward to the skin of the external genitalia. Their terminations are known as the *anterior scrotal (labial) arteries*, and anastomose with the corresponding posterior vessels from the internal pudendal artery.

5. The *deep femoral artery* (Figs. 573 to 575) is the largest branch of the femoral artery and nourishes the musculature of the thigh. It arises from the posterior surface of the femoral artery and passes downward in a slightly tortuous manner into the depths of the thigh, as a short thick trunk, rapidly diminishing in caliber and situated lateral to and behind the femoral artery. In the upper part of its course it is situated in front of the insertion of the iliopsoas and of the pectineus; in the lower part it is close to the femur, between the insertions of the adductor longus and adductor brevis, and its terminal branches pass through the adductor magnus to the posterior surface of the thigh. One of the two large circumflex branches, usually the medial, sometimes arises directly from the femoral artery, under which circumstances the profunda femoris is correspondingly diminished in size. Its branches are:

(*a*) The *medial circumflex femoral artery* (Figs. 574, 575, 577, and 717) arises from the first portion of the deep femoral (occasionally from the femoral itself), passes transversely inward behind the femoral artery and vein, and gives off a slender *superficial branch* which ramifies in

the anterior adductors (pectineus, adductor longus), while the main portion of the artery passes backward as the *deep branch* between the iliopsoas and the pectineus and courses around the neck of the femur above the lesser trochanter. This deep branch gives numerous twigs to the adductors, anastomoses with the deep branch of the obturator artery, sends branches to the articular capsule of the hip-joint, ramifies upon the posterior surface of the thigh and in the gluteal region, and ends by dividing into an ascending and a descending branch. The *ascending branch* passes upward between the quadratus femoris and the gemellus inferior, anastomoses with the gluteal arteries and partly with the lateral circumflex, and aids in the formation of the trochanteric rete. The descending branch passes between the quadratus femoris and the adductor minimus, ramifies in the adductor minimus, the adductor magnus, and the neighboring flexors, and anastomoses with the inferior gluteal and first perforating arteries.

(*b*) The *lateral circumflex femoral artery* (Figs. 574 and 575) arises opposite the medial circumflex, but usually at a somewhat lower level. At first it runs almost transversely outward between the branches of the femoral nerve, behind the rectus femoris and in front of the insertion of the iliopsoas, and then divides into a large descending branch and a smaller ascending branch. The *ascending branch* passes upward to the posterior surfaces of the sartorius, tensor fasciæ latæ and rectus femoris, partially supplies the glutæus medius and glutæus maximus, and extends to the vastus lateralis. The larger *descending branch* runs downward between the rectus femoris and vastus intermedius (in front of the latter muscle) and ramifies almost wholly in the quadriceps femoris. In addition to these two main branches of the artery, twigs are given off which pass horizontally outward, covered by the glutæus medius, and run around the neck of the femur to the gluteal region, where they become associated with the medial circumflex and the gluteal arteries in the trochanteric rete.

(*c*) The *first perforating artery* (Figs. 575 and 577), the uppermost and the largest of the perforating branches, reaches the posterior surface of the thigh by piercing the adductor magnus at the junction of the upper and middle thirds of the muscle, and divides into an ascending and a descending branch. The *ascending branch* supplies the glutæus maximus, the quadratus femoris, the adductor minimus, and the upper portion of the adductor magnus, and anastomoses with the inferior gluteal and with the circumflex femoral arteries, especially with the medial one. The *descending branch* supplies the greater portion of the adductor magnus, the flexors (particularly the biceps), and the origin of the vastus lateralis, gives off the *superior nutrient artery of the femur*, and anastomoses with the second perforating artery and with the muscular branches of the femoral and popliteal arteries.

(*d*) The *second perforating artery* (Figs. 575 and 577) is smaller than the first. After passing close to the insertion of the adductor brevis, it pierces the adductor magnus at about its middle, supplies the deep layers of the adductors, the flexors, and the vasti, and anastomoses with the branches of the other two perforating arteries.

(*e*) The *third perforating artery* (Figs. 577 and 578) is the terminal branch of the deep femoral artery. It pierces the adductor magnus just above the adductor opening and gives off the chief vessel for the nourishment of the femur, the *inferior nutrient artery of the femur*. It sends branches to the adductor magnus, the short head of the biceps, and the origins of the vasti, and anastomoses with the neighboring branches of the second perforating and popliteal arteries.

During its course through the thigh below the iliopectineal fossa the femoral artery gives off but few branches.

6. The *muscular branches* (Figs. 574 and 575) vary in number. They supply the sartorius, the adductors, and the quadriceps.

7. The *genu suprema* (*anastomotica magna*) *artery* (Figs. 573 to 575) arises from the femoral just before that vessel passes through the adductor opening. It runs to the internal condyle of the femur under cover of the sartorius muscle and in company with the saphenous nerve, to which it gives a small *saphenous artery*. It gives off muscular branches to the neighboring muscles, especially to the vastus medialis, and below the internal condyle becomes superficial and sends articular branches to the knee-joint. A larger branch, occasionally arising independently from the femoral artery, traverses the vastus medialis and also ends at the knee-joint by aiding in the formation of the articular rete.

By the anastomoses of the circumflex femoral arteries, of the obturator arteries, and the first perforating artery with the gluteal arteries and with each other, and also by the anastomoses between the branches of the femoral and hypogastric arteries, a large number of paths are provided in the posterior gluteal region which may play an important role in the development of the collateral circulation after an interruption in the continuity of either the femoral or the external iliac arteries.

THE POPLITEAL ARTERY.

The *popliteal artery* (Figs. 578 to 581, and 718) is the immediate continuation of the femoral, and throughout the greatest portion of its course lies deeply in the popliteal space. From the adductor opening it passes at first downward under cover of the semimembranosus, upon the posterior surface of the femur, to the upper apex of the lozenge-shaped popliteal fossa. It then traverses this space diagonally from above downward, being no longer covered by muscles, but partly concealed by the popliteal vein, which is somewhat lateral to it, and surrounded by fatty tissue which separates it from the popliteal surface of the femur and the posterior surface of the articular capsule of the knee-joint.

From the lower apex of the popliteal fossa the artery passes in front of the two heads of the gastrocnemius, lying between them and the popliteus, then in front of the tendinous arch of the soleus, and finally divides at this level in the popliteal canal into its two terminal branches, the anterior and posterior tibial arteries. In addition to proximal muscular branches which arise from the artery above the knee-joint and run to the biceps and the semimembranosus (anastomosing with the third perforating artery), the popliteal artery gives off the following branches:

1. The *lateral genu superior* (*superior external articular*) *artery* (Figs. 578, 582, and 718) arises at about the middle of the popliteal space, runs transversely outward above the external condyle between the lower extremity of the shaft of the femur and the insertion of the biceps, and then passes forward to become superficial at the external condyle of the femur below the vastus lateralis. It ramifies in the latter muscle and ends in the articular rete of the knee.

2. The *medial genu superior* (*superior internal articular*) *artery* (Figs. 575, 578, and 582) arises opposite the preceding vessel and pursues an analogous course. It runs medially between the femur and the semimembranosus and semitendinosus, and then forward between the femur and the gracilis, sartorius, and the tendinous insertion of the adductor magnus. Below the vastus

FIG. 575.—The nerves and vessels of the anterior surface of the thigh (deep layer).

Dissection as in Fig. 574, except that the rectus femoris and the adductor longus have also been divided. ** = Large muscular branch of the deep femoral artery.

FIG. 576.—The nerves and vessels of the posterior surface of the thigh (superficial layer).

Only the fascia has been removed. * Communication between small saphenous vein and branches of deep femoral vein.

FIG. 577.—The vessels and nerves of the posterior surface of the thigh (deep layer) and of the posterior gluteal region (middle layer).

* = Communication between small saphenous and deep femoral veins. ** Divided long head of biceps.

FIG. 578.—The arteries of the popliteal space.

The two heads of the gastrocnemius and the soleus have been divided and portions of the biceps and semimembranosus removed.

medialis and the tendinous insertion of the adductor magnus the artery becomes superficial at the internal condyle and then descends to the articular rete of the knee after giving branches to the neighboring muscles.

3. The *genu media* (*azygos articular*) *artery* (Fig. 578) arises below the middle of the popliteal space from the anterior surface of the popliteal artery, pierces the articular capsule of the knee-joint immediately above the oblique popliteal ligament, and enters the interior of the joint to be distributed chiefly to the cruciate ligaments and to the alar folds.

4. The *sural arteries* (Figs. 578, 579, and 718) are four or five in number and several may frequently arise from a common trunk. They take origin in the lower portion of the popliteal space and supply the triceps suræ, being especially distributed to the two heads of the gastrocnemius. Individual branches also run superficially in the groove between the two heads of the gastrocnemius and supply the integument.

5. The *lateral genu inferior* (*inferior external articular*) *artery* (Figs. 578 and 582) arises from that portion of the popliteal artery which is in front of the gastrocnemius, turns laterally and forward in front of the tendon of origin of the popliteus, is covered by the outer head of the gastrocnemius and by the tendon of insertion of the biceps, sends branches to these muscles, and terminates in the articular rete of the knee.

6. The *medial genu inferior* (*inferior internal articular*) *artery* (Figs. 575, 578, and 581) arises opposite the preceding vessel or at a somewhat lower level, passes medially beneath the inner head of the gastrocnemius at the upper margin of the popliteus, then forward around the lower border of the internal condyle of the tibia, is covered by the tendons of the pes anserinus and the tibial lateral ligament, gives off muscular branches and twigs to the ligaments, and descends upon the inner side to enter the articular rete of the knee.

THE POSTERIOR TIBIAL ARTERY.

The *posterior tibial artery* (Figs. 578, 580, 581, 584, and 585) arises at the bifurcation of the popliteal artery in the popliteal canal. It is the artery for the posterior surface of the leg and for the sole of the foot, and represents the direct continuation of the popliteal. It passes downward for a distance of 3 or 4 cm. between the soleus and the tibialis posterior, when it gives off its largest and most independent branch, the peroneal artery, which appears to be a third artery

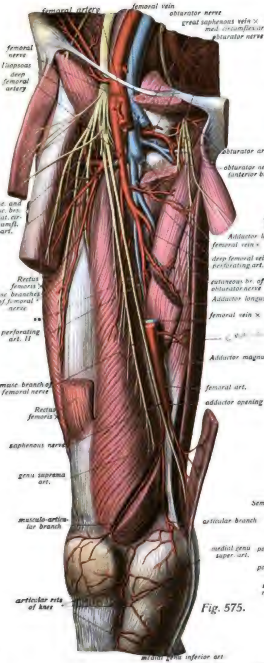


Fig. 575.

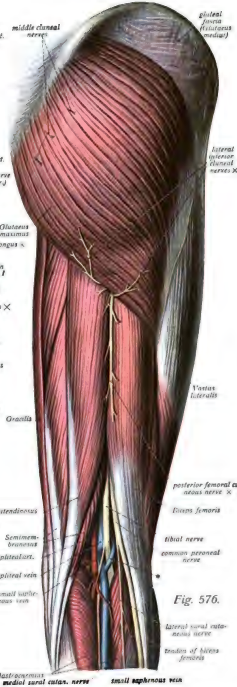


Fig. 576.

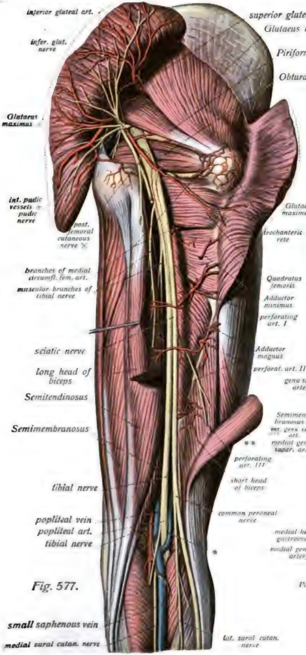


Fig. 577.

Fig. 578.

for the leg.* From this point the posterior tibial artery is considerably diminished in caliber and pursues a slightly tortuous course downward between the deeper layer of the musculature of the calf (the tibialis posterior and the flexor digitorum) and the inner segment of the soleus, gradually approaching the inner side of the leg and becoming superficial at the inner margin of the soleus. The tibial nerve is lateral to the artery throughout the entire course of the vessel, and in the lower third of the leg the artery and the nerve are superficially situated beneath the crural fascia, medial to the medial border of the tendo calcaneus, and behind the tendons of the tibialis posterior and flexor digitorum longus. Still holding the same relation to the tibial nerve, the posterior tibial artery enters the sole by passing beneath the laciniate ligament midway between the internal malleolus and the inner margin of the tendo calcaneus, and beneath the abductor hallucis (as viewed from the plantar surface) the artery divides into its two terminal branches, the medial and lateral plantar arteries.

During its course down the leg the posterior tibial artery gives off numerous muscular branches to the soleus and especially to the deeper muscles, and also some branches which pierce the interosseous membrane and supply the anterior muscles. The other branches are:

1. The *fibular branch* (Fig. 581), a large muscular branch to the soleus, which runs toward the head and neck of the fibula, supplies the muscles arising in this situation, and anastomoses with the lateral genu inferior artery.

2. The *peroneal artery* (Figs. 580 and 581) arises at an acute angle and passes downward situated deeply in the lateral portion of the leg; its course is nearly parallel with that of the posterior tibial and its caliber is almost as great. It at first lies between the soleus and the origin of the tibialis posterior or of the flexor hallucis longus, and lower down between the flexor hallucis longus and the interosseous membrane. It breaks up into its terminal ramifications below the external malleolus at the outer side of the calcaneus.

During its course between the muscles of the leg the peroneal artery gives off numerous muscular branches, particularly to the soleus, to the peronæi, and to the flexor hallucis longus, and also gives origin to the *nutrient artery of the fibula.* The distal as well as the terminal branches are designated by special names:

(*a*) The *perforating (anterior peroneal) branch* (Fig. 582) is usually but a small vessel which pierces the lower portion of the interosseous membrane, ramifies in the extensor digitorum and peronæus tertius, and ends in the lateral malleolar rete. This branch is occasionally large and either partly or wholly replaces the dorsal artery of the foot, in which case the peroneal artery is also unusually large.

(*b*) The *communicating branch* (Fig. 581) passes transversely, joining the posterior tibial artery. It runs above the talocrural articulation over the lower extremity of the tibia in front of the flexor digitorum longus, and ramifies in the bone, in the calcaneal tendon, and partly also in the muscles.

* The relation of these vessels may also be stated by saying that the popliteal artery subdivides into three branches: the anterior tibial artery, the posterior tibial artery, and the peroneal artery. The two latter branches are the actual terminals, the first branch having been previously given off. [It may be added that embryologically the peroneal is the primary artery of the leg and represents the original direct prolongation of the popliteal.—Ed.]

FIG. 579.—The vessels and nerves of the posterior surface of the leg (superficial layer).

The gastrocnemius has been divided and reflected.

FIG. 580.—The vessels and nerves of the posterior surface of the leg (middle layer).

Dissection as in Fig. 579, except that the soleus has also been divided and drawn aside.

FIG. 581.—The vessels and nerves of the posterior surface of the leg (deep layer).

Dissection as in Fig. 580, except that the popliteal canal has been opened and an oblique portion excised from the lower part of the flexor hallucis longus. The tibial nerve has been drawn to one side. * = Muscular branches.

FIG. 582.—The vessels and nerves of the anterior surface of the leg and of the dorsum of the foot.

The peronæus longus and extensor digitorum have been divided to expose the division of the common peroneal nerve. The extensor hallucis longus and the peroneal nerve have been drawn to one side and one band of the cruciate ligament removed.

(*c*) The *posterior lateral malleolar artery* (Fig. 581) joins with the anterior lateral malleolar branch of the anterior tibial artery to form the lateral malleolar rete (see page 75).

(*d*) The *lateral calcaneal branches* (Fig. 581) are terminals and unite with the medial calcaneal branches of the posterior tibial to form the calcaneal rete (see page 75).

3. The *nutrient artery of the tibia* usually arises together with the muscular branches and passes through the nutrient canal to the medullary cavity. In conformity with the size of this canal it is the largest nutrient artery in the body.

4. The *medial posterior malleolar artery* (Fig. 581) sends several branches between the flexor tendons and the internal malleolus, some of them being superficial to the tendons, to the internal malleolar rete (see page 75).

5. The *medial calcaneal branch* or *branches* (Fig. 581) arise just before the bifurcation of the posterior tibial in the vicinity of the laciniate ligament, and pass to the calcaneal rete.

The two terminal branches are distributed as follows:

6. The *medial plantar artery* (Figs. 584 to 586) is the smaller of the two terminals. It arises from the bifurcation of the posterior tibial above the abductor hallucis, and divides into a small superficial and a larger deep branch. The *superficial branch* is immediately beneath the plantar aponeurosis and ramifies in the abductor hallucis and in the integument. The *deep branch* is distributed to the muscles of the great toe, and at the base of this digit aids in the formation of the medial plantar digital artery of the great toe (see page 76).

7. The *lateral plantar artery* (Figs. 585 and 586), the larger terminal branch, runs obliquely across the proximal portion of the sole, situated deeply between the flexor digitorum brevis and the quadratus plantæ, toward the outer border of the foot, and then runs rather superficially, together with the lateral plantar nerve, through the lateral plantar sulcus. The termination of the artery passes between the abductor hallucis and the plantar interossei into the depths of the sole, where it pursues a curved course as the plantar arch (see page 75). In its course through the sole it gives off branches to the neighboring muscles, especially to the flexor digitorum brevis, the quadratus plantæ, and the abductor minimi digiti, and also gives origin to the artery for the lateral surface of the fifth digit, the *lateral plantar digital artery for the fifth digit*.

THE ANTERIOR TIBIAL ARTERY.

The *anterior tibial artery* (Figs. 581 to 583) is the artery for the anterior aspect of the leg and for the dorsum of the foot; its terminal branch, however, extends to the sole of the foot. It

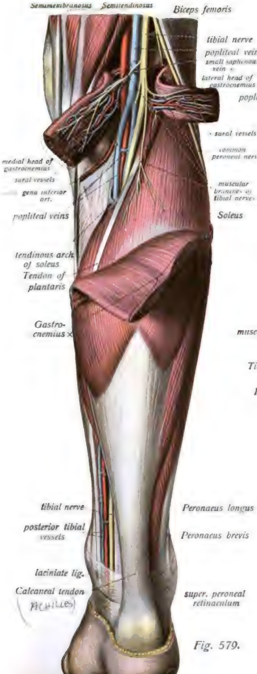


Fig. 579.

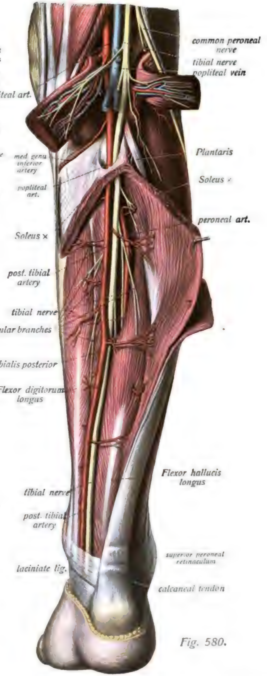


Fig. 580.

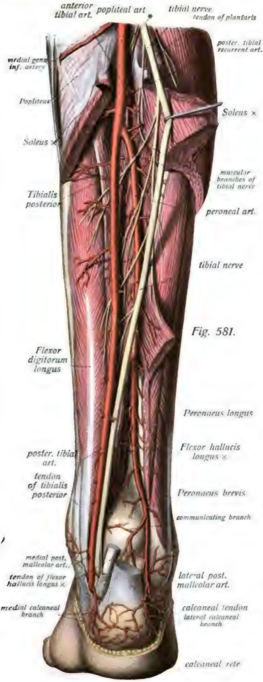


Fig. 581.

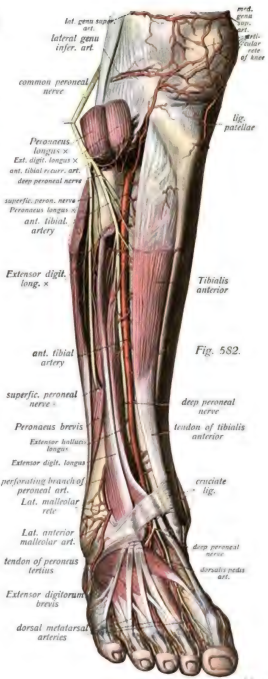


Fig. 582.

arises together with the posterior tibial artery at the bifurcation of the popliteal artery in the popliteal canal, and immediately after its origin passes forward between the tibia and fibula, above the interosseous membrane, to reach the anterior aspect of the leg. Upon the anterior surface of the interosseous membrane it passes downward medial to the deep peroneal nerve, being situated in the upper portion of its course in the interspace between the tibialis anterior and the extensor longus digitorum, and in the lower portion between the tibialis anterior and the extensor hallucis longus. As it passes behind and beneath the cruciate ligament to the dorsum of the foot, it is crossed by the extensor hallucis longus, so that at the lower extremity of the leg the anterior tibial artery is situated between the extensor digitorum and the extensor hallucis. Upon the dorsum of the foot the immediate continuation of the artery is termed the *dorsalis pedis*.

During its course in the leg the anterior tibial artery gives numerous muscular branches to the extensors. It also gives off the following specially named branches:

1. The *posterior tibial recurrent artery* (Fig. 581) arises from the anterior tibial before it reaches the anterior surface of the interosseous membrane, ascends toward the head of the fibula, and ramifies in the soleus and in the adjacent muscles. This artery is not always present.

2. The *anterior tibial recurrent artery* (Fig. 582) is a constant and rather large branch, which takes origin from the anterior tibial just after the latter vessel has passed the interosseous membrane. It ramifies in the origins of the extensor digitorum longus and tibialis anterior, and passes upward on the anterolateral surface of the knee-joint to terminate in the articular rete of the knee.

3. The *lateral anterior malleolar artery* (Figs, 582 and 583) passes to the lateral malleolus between the bone and the extensor digitorum longus and anastomoses in the lateral malleolar rete with the perforating branch of the peroneal artery and with the lateral posterior malleolar artery.

4. The *medial anterior malleolar artery* (Fig. 583), occasionally double, passes between the lower end of the tibia and the tendons of the tibialis anterior and extensor hallucis to the medial malleolar rete, where it anastomoses especially with the medial posterior malleolar artery from the posterior tibial.

THE DORSAL ARTERY OF THE FOOT.

The *dorsal artery of the foot* (*dorsalis pedis*) (Figs. 582 and 583) is the immediate continuation of the anterior tibial artery. It runs forward superficially beneath the fascia of the dorsum of the foot, in the interspace between the tendons of the extensor hallucis longus and extensor hallucis brevis, to the first interosseous metatarsal space, where it divides into its two terminal branches, the first dorsal metatarsal artery and the deep plantar branch. Before this terminal bifurcation, the artery, which is otherwise superficial, is crossed by the extensor hallucis brevis. In addition to the terminal branches and small twigs to the neighboring structures it gives off the following branches:

1. The *lateral tarsal artery* (Fig. 583) arises from the commencement of the artery and passes beneath the extensor digitorum and the extensor hallucis toward the outer border of the foot, giving muscular branches to both short extensors and twigs to the joints and bones of the tarsus. Branches also run proximally to enter the lateral malleolar rete, and a rather larger branch passes distally to connect with the arcuate artery.

FIG. 583.—The vessels and nerves of the dorsum of the foot (deep layer).

The cruciate ligament has been removed as has also the greater portion of the extensor digitorum longus, the extensor digitorum brevis, and the extensor hallucis brevis. The superficial nerves have also been cut away except upon the toes. + External (motor) terminal branch of the deep peroneal nerve. + + Articular filaments.

FIG. 584.—The superficial vessels and nerves of the sole of the foot.

The laciniate ligament has been divided. * Plantar cutaneous branches of the medial plantar nerve. ** Plantar cutaneous branches of the lateral plantar nerve.

2. The *medial tarsal arteries* (Fig. 583) are two or three small twigs which arise more distally than the lateral tarsal artery. They run toward the medial border of the foot and end in the medial malleolar rete.

3. The *arcuate (metatarsal) artery* (Figs. 582 and 583) arises over the distal portion of the tarsus and pursues a slightly curved course beneath the extensor digitorum brevis to the outer border of the foot in the vicinity of the tuberosity of the fifth metatarsal bone, and, by anastomosing by several branches with the lateral plantar artery, forms the wide-meshed *dorsal rete of the foot.* From this rete arises the *lateral dorsal digital artery of the fifth digit.* The arcuate artery gives small twigs to the neighboring bones and joints and also three larger branches. These are:

The *second, third,* and *fourth dorsal metatarsal arteries* (Fig. 583), which run upon the dorsal surfaces of the three lateral dorsal interossei, which they supply. At the base of the toes each dorsal metatarsal artery divides into two *dorsal digital arteries* for the contiguous surfaces of the toes, these vessels being termed respectively the *medial* and the *lateral dorsal digital arteries.* They are distributed in exactly the same manner as the analogous vessels in the fingers.

4. The *first dorsal metatarsal artery* (Fig. 583), the smaller terminal branch, runs over the dorsal surface of the first dorsal interosseous muscle, passes beneath the extensor hallucis brevis, and divides at the base of the great toe into the *lateral dorsal digital artery of the hallux* and the *medial dorsal digital artery of the second digit.* It also occasionally gives off the *medial dorsal digital artery of the hallux,* the origin of which is variable (see page 76).

5. The *deep plantar branch* (Figs. 583 and 586), the larger terminal of the dorsalis pedis, passes between the heads of the first dorsal interosseous muscle to reach the sole of the foot, where it joins the lateral plantar artery to form the plantar arch (see page 75).

THE ARTICULAR RETIA OF THE LOWER EXTREMITY.

In the lower extremity retia are found not only in the neighborhood of the main joints but also over projecting bony prominences. These retia are:

1. The *trochanteric rete* (Figs. 577 and 717) is a small network situated over the great trochanter, and is supplied by branches of the superior gluteal, inferior gluteal, and lateral circumflex femoral arteries. It is, therefore, an anastomosis of branches from the hypogastric and femoral arteries.

2. The *articular rete of the knee* (Figs. 573, 574, and 582) is the largest articular rete of the entire body. It is situated over the anterior and lateral surfaces of the knee-joint, partly superficial as the *patellar rete* upon the anterior surface of the patella, and partly behind this bone and

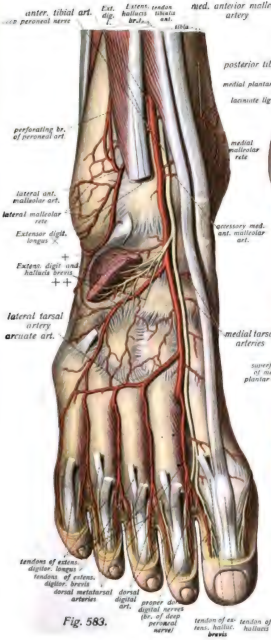


Fig. 583.

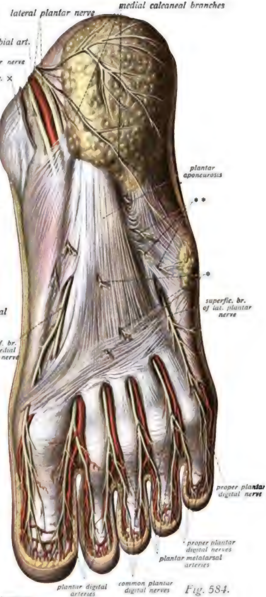


Fig. 584.

the patellar ligament and laterally to them behind the fascia and the lateral ligaments, and in the interior of the joint. It is formed by branches of the genu suprema from the femoral artery, by twigs from the five genual branches of popliteal artery, by the tibial recurrent arteries (by the anterior and partly also by the posterior), by the anterior tibial artery, and usually also by the fibular branch of the posterior tibial. Anastomoses occur not only between the branches coming from above and from below on the same side but also transversely between the arteries of the lateral and medial surfaces of the joint.

3. The *medial malleolar rete* (Fig. 583) is situated superficially upon the medial malleolus, and is formed by the anastomoses of twigs of the medial anterior malleolar artery from the anterior tibial, of the medial posterior malleolar artery from the posterior tibial, and of the medial tarsal arteries from the dorsalis pedis.

4. The *lateral malleolar rete* (Figs. 582 and 583) is placed superficially upon the lateral malleolus, and is formed by twigs from the lateral anterior malleolar artery from the anterior tibial, from the lateral posterior malleolar and perforating branches of the peroneal artery, and from the lateral tarsal artery from the dorsalis pedis.

5. The *calcaneal rete* (Fig. 581) is a superficial network between the calcaneus and the fatty layer of the sole, and is formed by the lateral calcaneal branch of the peroneal artery, by the medial calcaneal branch of the posterior tibial, and by anastomoses with the two malleolar retia.

6. The *dorsal rete of the foot* (Fig. 583) is a wide-meshed network upon the dorsal surfaces of the distal tarsal bones and of their articular capsules, and is formed by anastomoses of the arcuate and lateral plantar arteries.

THE ARTERIES OF THE FOOT.

In a general way the arteries of the dorsum of the foot (Fig. 583) are distributed like the analogous vessels in the hand. The dorsal artery of the foot corresponds to the radial artery in the hand, and its ramifications have previously been described. In the sole of the foot, however, the conditions are markedly different, since there is but a single arterial arch in this situation, the *plantar arch* (Fig. 586), formed by the anastomosis of the deep terminal branch of the lateral plantar artery with the deep plantar branch of the dorsal artery of the foot. It is convex anteriorly, is situated near the middle of the length of the metatarsal bones in immediate contact with the plantar interossei, and is covered upon its plantar aspect by the oblique head of the adductor hallucis. In addition to small muscular and articular branches, the plantar arch gives origin to four *plantar metatarsal arteries* (Figs. 584 to 586), which run toward the toes in the interosseous spaces. The largest of these is the medial *first plantar metatarsal artery* and the smallest is the lateral *fifth plantar metatarsal artery*. The first plantar metatarsal artery runs between the two tendons of insertion of the flexor brevis hallucis and always unites with the termination of the deep branch of the medial plantar artery to form the *internal* (*tibial*) *plantar digital artery of the hallux*. It then divides into the *lateral* (*fibular*) *plantar digital artery of the hallux* and the *medial* (*tibial*) *plantar digital artery of the second digit*. After passing above the transverse head of the adductor hallucis, each of the remaining plantar metatarsal arteries divides at the bases of the toes into a *medial* (*tibial*) and a *lateral* (*fibular*) *plantar digital artery* for the contiguous surfaces of the digits.

FIG. 585.—The vessels and nerves of the sole of the foot (middle layer).

The abductor hallucis has been divided and the greater portion of the flexor digitorum brevis removed together with the plantar aponeurosis. * = Branch to flexor digitorum brevis. ** = Branch to quadratus plantæ. *** = Divided cutaneous branch.

FIG. 586.—The vessels and nerves of the sole of the foot (deep layer).

Dissection as in Fig. 585. There have also been divided the tendon of the flexor hallucis longus, the quadratus plantæ, and the tendons of the flexor digitorum longus, the oblique head of the adductor hallucis, and the medial plantar nerve.

Every toe in the foot, like every finger in the hand, has four arteries—two small dorsal arteries, which extend only as far as the second phalanx, and two larger plantar arteries.

These are:

(a) IN THE DORSUM OF THE FOOT (Fig. 583).

1. The *medial (tibial) dorsal digital artery of the hallux*, usually from the first dorsal metatarsal artery, sometimes also partly from the medial plantar artery.

2. The *lateral (fibular) dorsal digital artery of the hallux* and the *medial (tibial) dorsal digital artery of the second digit* from the first dorsal metatarsal artery.

3. The *lateral (fibular) dorsal digital artery of the second digit* and the *medial (tibial) dorsal digital artery of the third digit* from the second dorsal metatarsal artery.

4. The *lateral (fibular) dorsal digital artery of the third digit* and the *medial (tibial) dorsal digital artery of the fourth digit* from the third dorsal metatarsal artery.

5. The *lateral (fibular) dorsal digital artery of the fourth digit* and the *medial (tibial) dorsal digital artery of the fifth digit* from the fourth dorsal metatarsal artery.

6. The *lateral (fibular) dorsal digital artery of the fifth digit* from the dorsal rete of the foot.

(b) IN THE SOLE OF THE FOOT (Figs. 584 to 586).

1. The *medial (tibial) plantar digital artery of the hallux* from the first plantar metatarsal and the medial plantar arteries.

2. The *lateral (fibular) plantar digital artery of the hallux* and the *medial (tibial) plantar digital artery of the second digit* from the first plantar metatarsal artery.

3. The *lateral (fibular) plantar digital artery of the second digit* and the *medial (tibial) plantar digital artery of the third digit* from the second plantar metatarsal artery.

4. The *lateral (fibular) plantar digital artery of the third digit* and the *medial (tibial) plantar digital artery of the fourth digit* from the third plantar metatarsal artery.

5. The *lateral (fibular) plantar digital artery of the fourth digit* and the *medial (tibial) plantar digital artery of the fifth digit* from the fourth plantar metatarsal artery.

6. The *lateral (fibular) plantar digital artery of the fifth digit* from the lateral plantar artery.

THE VEINS.

The Development of the Venous System.—In the course of embryonic life the venous system is greatly changed from its original condition. In the first stage of the embryonic circulation two large curved venous trunks, designated as the *ducts of Cuvier*, each of which collects the blood from its side of the body, empty into the heart by a transverse connection, the *sinus reuniens*. This sinus reuniens is subsequently included in the heart and becomes the sinus of the venæ cavæ of the right atrium (see Vol. II, pages 171 and 176).

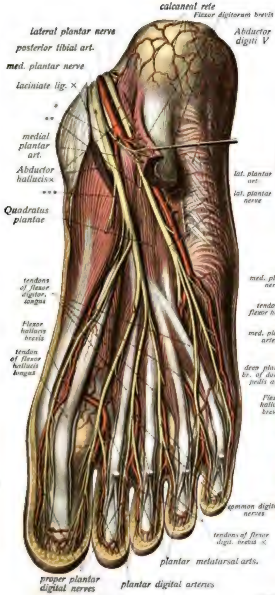


Fig. 585.

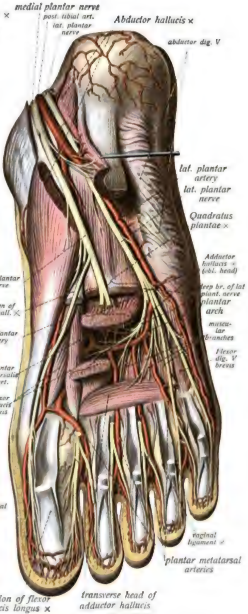


Fig. 586.

Each duct of Cuvier is formed by the union of two large venous trunks, the primitive *jugular vein* from the cephalic region and the *cardinal vein* from the body wall (and from the still relatively small lower half of the body). [The primitive jugular vein subsequently becomes the internal jugular, while the external jugular appears later as a prolongation downward of the facial vein.—ED.] The subclavian vein originates as a lateral branch of the primitive jugular vein. The cardinal veins are the forerunners of the azygos and hemi-azygos veins, and their radicles collect the blood from the body-walls and also from the relatively small lower extremities, the inferior vena cava not existing at this time, and the umbilical vein passing directly to the sinus reuniens. The first-formed portions of the venous system are consequently paired throughout.

The first modification of this primitive condition occurs in the region of the ducts of Cuvier. The oblique position of the heart favors the flow of the venous blood to the right half of the body of the embryo, and the growth of the left duct of Cuvier becomes arrested, a portion of its blood passing into the right duct through a transverse anastomosis, the subsequent left innominate vein.* The right duct of Cuvier becomes the superior vena cava, while the left duct becomes obliterated from the origin of the previously mentioned transverse anastomosis to the terminal portion, which has come to lie in the coronary sulcus as a result of the rotation of the heart and which forms the coronary sinus and the left oblique vein of the atrium. The obliterated portion becomes the fold (ligament) of the left vena cava (see Vol. II., page 182).

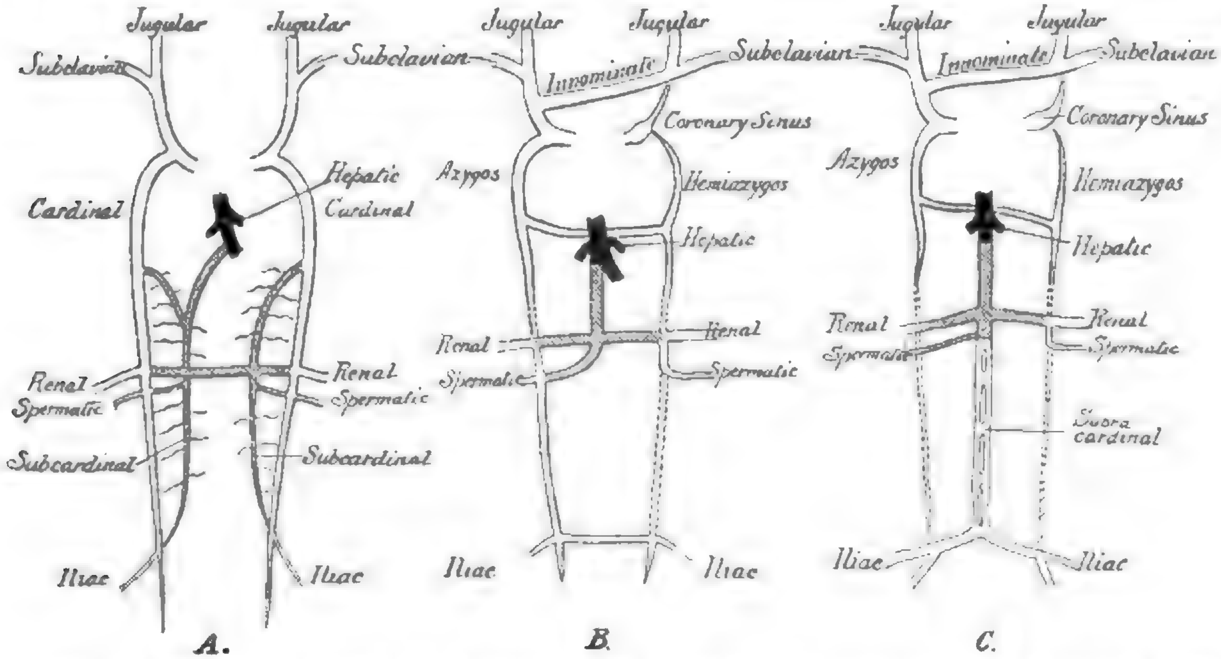


FIG. 586, *a*.—Diagrams showing the development of the inferior vena cava: In *A* is shown the hepatic portion together with the cardinal and subcardinal veins; in *B* is shown the formation of the postrenal portion from the right cardinal, and in *C* its formation by the fusion of the supracardinals. The hepatic portion is represented in solid black; the subcardinal portion is shaded.

[The inferior vena cava is represented in the earlier stages only by that portion of the adult vein which intervenes between the entrance of the hepatic veins and the right atrium, this portion representing the upper end of the ductus venosus (see Vol. II., page 169). The drainage of the abdominal walls, the paired abdominal and the pelvic viscera, and the lower limb passes at this stage through the cardinal vein. Later, by the anastomosis of mesenterial afferents of the cardinals, there is formed, ventral to each kidney, a longitudinal stem, the *subcardinal veins*, and between these, especially at the level of the renal veins, cross anastomoses are formed, and the right subcardinal, furthermore, makes connection above with the portion of the vena cava already in existence. Later, the left subcardinal practically disappears and the upper abdominal portions of both cardinals also degenerate, so that the right subcardinal becomes the drainage

* The right innominate vein originates from the terminal portion of the primitive jugular vein (between the right duct of Cuvier and the orifice of the internal jugular and subclavian veins).

stem for both kidneys and forms a second segment of the vena cava inferior—namely, that intervening between the original portion derived from the ductus venosus and the level of the renal veins—or it may be as far down as the right internal spermatic vein.

As regards the formation of the lowest portion of the inferior cava, two possibilities exist. It is usually described as developing from the lower portion of the right cardinal, the left common iliac vein opening into this vein by means of a cross connection which develops between the two cardinals at the level of the entrance of the iliacs into them. The lower part of the left cardinal then disappears, except the small portion intervening between the left renal and the left internal spermatic veins, and the persistent portion of the right cardinal unites with the portion of the vena cava formed by the right subcardinal.

According to another view, the lower or postrenal portion of the inferior cava is formed by the coming together of two additional longitudinal stems, the *supracardinals* (McClure), which develop along a line dorsal to both the cardinals and the subcardinals, and eventually completely replace the lower portions of the original cardinals. Numerous cross anastomoses occur between the cardinals and the collaterals, and by means of these the iliac and lumbar veins transfer their blood from the cardinals to the collaterals. The right internal spermatic vein transfers its connection from the right cardinal to the lower part of the persistent right subcardinal, while the left internal spermatic retains its opening into the left cardinal, the portion of that vein between the entrances of the internal spermatic and renal veins persisting.—Ed.]

The Veins of the Lesser or Pulmonary Circulation.

THE PULMONARY VEINS.

In the vicinity of the root of the lung upon either side there are usually formed two veins, known as the *right* and *left pulmonary veins* (Figs. 447, 448, 519, and 523). They are short, wide, valveless trunks about 1½ cm. in length, and arise in a rather variable manner within the root of the lung by the coalescence of the larger veins of the lung as they lie in the pulmonary hilus below the large branches of the bronchi.

A superior and an inferior pulmonary vein come from each lung. The two veins from each lung empty close together into the left atrium (see Vol. II., page 179), while the terminations of the veins of opposite sides are separated from each other by a distance of about 3 cm. All four veins pierce the pericardium before opening into the atrium.

The right and the left pulmonary veins do not pursue exactly the same course. The right veins are somewhat longer than the left and run in the pericardium behind the lower portion of the superior vena cava and the sinus of the venæ cavæ of the right atrium, but their course, like that of the somewhat shorter vessels of the left side, is almost transversely from the pulmonary hilus to the left atrium.

The pulmonary veins carry arterial blood—*i. e.*, blood rich in oxygen and poor in carbon dioxide—and not venous blood, like the systemic veins. In contrast to the pulmonary arteries, which belong exclusively to the pulmonary circulation, the pulmonary veins receive a few bronchial veins and anastomose with small veins of the mediastinum, so that they carry traces of the venous blood of the systemic circulation.

The Veins of the Systemic Circulation.

The veins of the systemic circulation which collect the blood distributed by the branches of the aorta do not unite to form a single trunk, but are composed (1) of the *cardiac veins*, which empty separately into the heart, and (2) of the two *venæ cavæ*, which correspond to the remaining branches of the aorta. The *superior vena cava* carries the blood from the upper half of the body

to the heart, while the *inferior vena cava* carries the blood from the lower half. It should be noted, however, that a portion of the blood from the lower half of the body—namely, part of that derived from the posterior abdominal walls—is conducted to the superior vena cava by the azygos vein.*

THE CARDIAC VEINS.

Almost all of the *cardiac veins* (Figs. 536 and 537) empty into a large common trunk, the *coronary sinus* of the heart, which delivers its blood to the right atrium. Some of the smaller veins, however, empty by separate orifices.

I. The *coronary sinus of the heart* (Fig. 537) is a short, broad, thick, valveless trunk, situated in the posterior portion of the coronary sulcus of the heart, and is the direct continuation of the great cardiac vein. In addition to this vein it also receives the middle and the small cardiac as well as a few other small veins. Its tributaries are:

1. The *great cardiac vein* (Figs. 536 and 537), the largest of all the cardiac veins, is valveless like its fellows, and seems to be the immediate continuation of the coronary sinus in the posterior portion of the coronary sulcus. It originates in a vein which accompanies the anterior descending branch of the left coronary artery in the anterior longitudinal sulcus of the heart, and collects the blood from the anterior surface of the two ventricles. During its course in the coronary sulcus it receives other veins from the substance of the left ventricle, particularly the following vessels, as well as a small vein from the left auricle:

(*a*) The *posterior vein of the left ventricle* (Fig. 537) arises upon the diaphragmatic surface of the heart in the region of the apex, where it anastomoses with the radicles of the middle cardiac vein. It runs almost parallel with the great longitudinal sulcus and empties into the great cardiac vein.

(*b*) The *oblique vein of the left atrium*—vein of Marshall—(Fig. 537) collects the blood from the posterior wall of the left atrium and runs obliquely over the posterior surface of this portion of the heart to the great cardiac vein. Together with the coronary sinus it forms the remaining portion of the left superior vena cava of embryonic life. A band of connective tissue extends from it to the left pulmonary veins, and beyond them to the obliterated portion of the left superior vena cava and is known as the *ligament (fold) of the vena cava (vestigial fold of the pericardium)*. The oblique vein of the left atrium empties at the junction of the great cardiac vein with the coronary sinus, and its orifice may be taken as the boundary between these two structures.

2. The *middle cardiac vein* (Fig. 537), the second largest tributary of the coronary sinus, arises in the neighborhood of the apex and is connected by anastomoses with the posterior vein of the left ventricle and with the radicles of the great cardiac vein. It runs upward alongside of the posterior descending branch of the right coronary artery in the posterior longitudinal sulcus, receives veins from the posterior surfaces of both ventricles, and empties into the coronary sinus just before this structure enters the right atrium.

3. The *small cardiac vein* (Fig. 537) is smaller than the preceding vessel and is not always

* It has previously been mentioned (see Vol. II., page 165) that the tributaries of the veins of the systemic circulation do not correspond either in number or in their relations with the similarly named arterial branches.

FIG. 587.—The large venous trunks of the thoracic cavity as viewed from in front and somewhat from the right.

The aorta has been removed, the superior vena cava divided just before entering the pericardium, and the inferior vena cava almost entirely cut away.

present. It arises near the right margin of the right ventricle, accompanies the right coronary artery in the right portion of the coronary sulcus, and empties into the coronary sinus or into the preceding vessel, which not infrequently replaces it entirely.

II. The *anterior cardiac veins* (Fig. 536) are usually several vessels of fair size which collect the blood from the anterior surface of the right ventricle. They pass above the right half of the anterior portion of the coronary sulcus below the margin of the right auricle and empty separately into the right atrium.

III. The *smaller cardiac veins* are minute atrial vessels, situated especially in the wall of the right atrium and in the atrial septum, and empty into the right atrium by the Thebesian foramina (see Vol. II., page 177).

THE SUPERIOR VENA CAVA.

The *superior vena cava* (Figs. 462, 518, 519, 533, 534, 536, 537, 587, and 588) is a thick, valveless trunk about 6 cm. in length, which runs almost exactly from above downward behind and beside the right border of the sternum, almost parallel with the ascending aorta. Its course is fairly straight, although its upper extremity lies more to the left and anteriorly and its lower extremity more to the right and posteriorly. Throughout its entire length it is situated within the thoracic cavity and its lower portion is also within the pericardium, its medial surface being invested for a considerably greater distance than its lateral. The site of entrance into the right atrium corresponds to the level of the sixth or seventh thoracic vertebra and to that of the attachment of the third right costal cartilage to the body of the sternum. The upper extremity of the superior vena cava, where it is formed by the junction of the two innominate veins, lies behind the attachment of the first right costal cartilage to the sternum, and in front of it there is consequently, in addition to the right border of the sternum, the lower portion of the first, the second, and part of the third right costal cartilages. Since the ascending aorta is more anterior than the superior vena cava its most marked dilatation (the great sinus, see page 19) partly overlaps the medial border of the vein, and the right phrenic nerve runs along that portion of its lateral wall which is situated above the pericardium. A portion of the thymus gland is situated anteriorly, and posteriorly are found the right branch of the pulmonary artery, the right pulmonary veins, and the right bronchus. Within the pericardial cavity the superior vena cava is in relation anteriorly with the right atrium and to the left with the root of the aorta.

In addition to the two innominate veins, which are to be regarded as the roots of the superior vena cava, this great trunk receives only a single large branch, the azygos vein.

THE AZYGOS AND HEMI-AZYGOS VEINS.

The *azygos vein* is not actually an unpaired vein, as its name implies, since there is upon the left side a corresponding structure, the *hemi-azygos vein*, which, however, is usually incom-

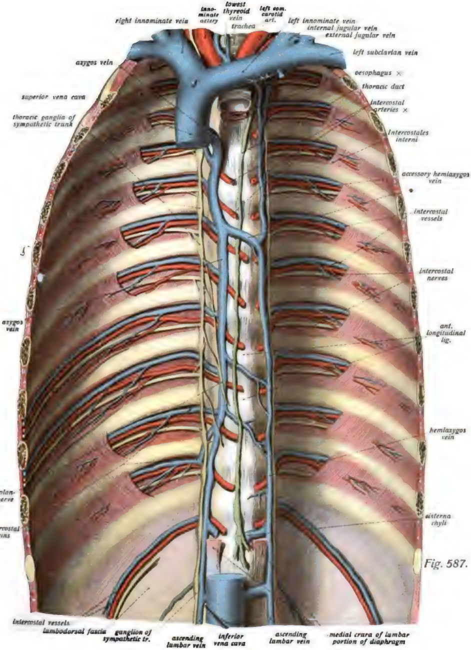

tano-
minate
artery
lowest
thyreoid
vein
left com.
carotid
art.
right innominate vein
trachea
left innominate vein
internal jugular vein
external jugular vein
left subclavian vein
azygos vein
oesophagus ×
thoracic duct
superior vena cava
intercostal
arteries ×
thoracic ganglia of
sympathetic trunk
Intercostales
interni
accessory hemiazygos
vein
intercostal
vessels
intercostal
nerves
azygos
vein
ant.
longitudinal
lig.
hemiazygos
vein
great splan-
chnic nerve
cisterna
chyli
intercostal
veins
intercostal vessels
lumbodorsal fascia
ganglion of
sympathetic tr.
ascending
lumbar vein
inferior
vena cava
ascending
lumbar vein
medial crura of lumbar
portion of diaphragm

Fig. 587.

pletely developed, is much smaller than the azygos vein, and empties its blood either partly or wholly into the latter. The two veins are the unequally persistent remains of the embryonic cardinal veins (see page 77).

The *azygos* (*vena azygos major*) *vein* (Figs. 462, 538, and 587) is a large, valveless, or almost valveless vein; situated upon the right side of the body in front of the lateral surfaces of the thoracic vertebræ, and serves chiefly for the reception of the right, and indirectly also for a portion of the left intercostal vein. It arises in the space between the middle and internal crura of the lumbar portion of the diaphragm as the immediate continuation of the right ascending lumbar vein, and empties into the superior vena cava just before this structure enters the pericardium. It pursues a fairly straight, at most only a slightly tortuous course, upward to the level of the body of the third thoracic vertebra, and is situated in the posterior mediastinum in front of the right intercostal arteries and to the right of the thoracic aorta and of the œsophagus. In front of the third thoracic vertebra, the vein passes anteriorly and curves over the root of the right lung to the superior vena cava, into the posterior wall of which it empties just before the cava enters the pericardium. The concavity of the curve of the azygos vein is directed downward.

The *hemi-azygos* (*vena azygos minor*) *vein* (Figs. 462 and 587) is considerably smaller than the azygos. It arises in a similar manner upon the left side between the lumbar crura of the diaphragm from the left ascending lumbar vein, and runs upward upon the left surfaces of the bodies of the lower thoracic vertebræ in the posterior mediastinum, to the left and behind the thoracic aorta and in front of the left intercostal arteries. At the middle of the thoracic vertebral column several transverse branches usually connect it with the azygos vein, into which it finally empties by a larger transverse branch.

The azygos and hemi-azygos veins receive as chief tributaries the intercostal veins, the azygos either receiving all the right intercostal veins or else the upper right intercostal veins form a supreme intercostal vein, corresponding to the artery, which may empty into the azygos vein, but usually terminates in the right innominate vein (see page 83).

The upper left intercostal veins do not empty into the actual hemi-azygos vein, this usually terminating at the middle of the thoracic vertebral column, but into a descending vein, the *accessory hemi-azygos* which represents a left supreme intercostal vein and consequently almost always anastomoses with the left innominate vein. After receiving the upper left intercostal veins it descends to join the hemi-azygos or empties with this structure (more rarely independently) into the azygos vein.

The tributaries of the azygos and hemi-azygos veins are:

1. The *ascending lumbar vein* (Figs. 587 and 716) arises upon either side from the sacral and lumbar veins near the promontory of the sacrum behind the psoas major and passes upward behind this muscle. It anastomoses with the lumbar veins, with the inferior vena cava (especially the right vein), and with the renal vein, and at the lumbar portion of the diaphragm becomes the azygos or the hemi-azygos vein, as the case may be.

2. The *intercostal veins* (Figs. 538 and 587) accompany the arteries of the same name in the posterior portions of the intercostal spaces, and are situated above and somewhat in front of them. The upper ten intercostal veins are connected anteriorly with the branches of the

internal mammary veins, and are provided with valves at their junctions with the azygos or hemi-azygos veins.

Each vein receives a very large *dorsal branch*, which corresponds with the dorsal branch of the intercostal artery and receives venous blood from the dorsal musculature and, by means of a *spinal branch*, the blood from the numerous vertebral veins. The intercostal veins always anastomose with the veins of the axilla by means of the costo-axillary veins (see page 93) and with each other; the lower ones also anastomose with the veins of the diaphragm and of the abdominal muscles.

THE VEINS OF THE VERTEBRAL COLUMN.

Throughout the entire length of the vertebral column, both upon the anterior and upon the posterior surfaces of the vertebral bodies, there are numerous venous plexuses which empty the greater portion of their blood into the veins of the body wall (the intercostal and the lumbar veins).

1. In the spongy substance of the vertebral bodies there are veins whose walls are devoid of muscular tissue and which pursue a radiating course. These are the *basivertebral veins*, and they empty into the longitudinal vertebral sinuses by transverse connecting branches which pass between the posterior longitudinal ligament and the posterior surfaces of the vertebral bodies.

2. The *longitudinal vertebral sinuses* are paired columns of venous plexuses, situated upon the posterior surfaces of the vertebral bodies to either side of the posterior longitudinal ligament. These veins also lack muscular tissue in their walls, and are especially well developed at the level of the middle of the vertebral bodies, where they are connected by transverse branches, and are relatively smaller opposite the intervertebral fibrocartilages.

3. The *intervertebral veins* are venous trunks which accompany the spinal nerves; they are plexiform derivatives of the longitudinal sinuses and of the external and internal vertebral plexuses, and empty into the vertebral vein (see page 81) in the neck, into the intercostal veins in the thorax, into the lumbar veins in the loin, and into the lateral sacral veins in the sacral region. They also usually receive the *anterior* and the *posterior external* * *spinal veins*, which are situated upon the surface of the spinal cord and accompany the anterior and the posterior spinal arteries.

4. The *external vertebral venous plexuses* are networks situated upon the outer surface of the vertebral column; they are subdivided into small anterior and larger posterior plexuses. The *anterior vertebral venous plexuses* are well developed only in the cervical region, where they are situated in front of the vertebral bodies and the longus capitis and longus colli muscles and are connected with the intervertebral veins. The much larger *posterior vertebral venous plexuses* lie upon the posterior surface of the vertebral column and the short muscles of the back; they receive blood from these muscles and from the vertebræ themselves and empty, either by means of the intervertebral veins or directly, into the spinal branches of the vertebral, intercostal, lumbar, and lateral sacral veins.

5. The *internal vertebral venous plexuses* are venous networks which are situated between the spinal dura mater and the periosteum throughout the entire length of the vertebral canal, and which anastomose with the posterior venous plexuses by branches which pierce the ligamenta flava. Transverse branches form plexiform communications of the individual plexuses with each other and with the longitudinal vertebral sinuses, so that at every vertebra a circular venous plexus is formed within the dura of the spinal cord. These plexuses, which are found throughout the entire length of the vertebral canal, are known as the *venous vertebral retia*.

THE INNOMINATE VEINS.

The *innominate veins* (Figs. 451, 452, 539, 551, 587, 588, 700, and 701) are the actual roots of the superior vena cava, to which they conduct the blood from the half of the head and neck and from the upper extremity of the same side, and they also receive the chief lymphatic trunks of the body (see page 106). The left innominate vein in addition receives the blood from the upper portion of the thoracic cavity and from the anterior thoracic wall.

The innominate vein arises upon either side in the superior thoracic aperture, behind the sternoclavicular joint and the origins of the sternohyoideus and sternothyreoideus, by the junction

* The veins coursing in the interior of the spinal cord are known as the *internal spinal veins*.

of the internal jugular, external jugular, and subclavian veins. This point is designated as the venous angle (right and left). One of the smaller venous tributaries occasionally also empties in this situation, or the external jugular vein does not pass directly to the venous angle, but indirectly by joining with one of the other two veins, especially with the subclavian, close to the venous angle.

Both innominate veins are valveless, but they are of unequal length and their courses and relations are also dissimilar. The right innominate vein is short and runs downward from the right venous angle behind the first costal cartilage and lateral to the bifurcation of the innominate artery, to the superior vena cava. The left innominate vein is twice as long as the right, and runs obliquely, although almost horizontally, behind the manubrium of the sternum, covered by the thymus gland, in front of the origins of the left common carotid, left subclavian, and innominate arteries, and immediately above the arch of the aorta. It possesses more tributaries than the right, among those peculiar to it being the vena thyreoidea ima, which descends in the median line of the neck, and also the thymic veins; it is consequently somewhat larger than the right vein.

In addition to the three roots the innominate veins also receive the following veins:

1. The *inferior thyreoid veins* (Fig. 588) correspond only in part with the arteries of the same name and their tributaries are even more variable. They lie deeply in the median region of the neck, mostly behind the sternohyoid and sternothyreoid muscles, and collect the blood from the lower portion of the thyreoid gland, from the lower portions of the larynx and pharynx, from the cervical portion of the œsophagus, and from the upper portion of the trachea. At the lower margin of the isthmus of the thyreoid gland they form an unpaired network, the *unpaired thyreoid venous plexus*, which gradually passes into an unpaired vessel, the *vena thyreoidea ima*, descending in front of the trachea and emptying into the left innominate vein behind the manubrium of the sternum. In addition there is usually also a *paired inferior thyreoid vein* which collects the blood from the lower portions of the lateral lobes of the thyreoid gland, anastomoses with the preceding vessels, and empties either into the corresponding innominate or into the lower portion of the internal jugular vein.

2. The *thymic veins* (Fig. 588) are small venous trunks from the thymus gland, the majority of which empty into the left innominate vein.

3. The *pericardiac veins* (Figs. 461 and 462), the *superior phrenic veins* (accompanying the pericardiacophrenic artery), the *anterior bronchial veins*, the *anterior mediastinal veins*, the *œsophageal veins*, and the *tracheal veins* are small venous branches coming from the parts indicated by their names, and usually emptying into one of the innominate veins or occasionally into the superior vena cava.

4. The *internal mammary vein* (Fig. 553) accompanies the terminal portion of the similarly named artery, to which it corresponds in a general way. Its radicles, the *superior epigastric* and *musculophrenic veins*, accompany the corresponding arteries as venæ comitantes, and it also receives the *anterior intercostal veins*, occasionally the *superior phrenic veins* and *sternal* and *perforating branches*. Sometimes the internal mammary veins of both sides empty into the left innominate vein.

5. The *supreme intercostal vein* (Figs. 538 and 587) differs upon the two sides. The left

FIG. 588.—The deep veins and arteries of the neck and the great venous and arterial trunks of the thorax.

Upon both sides the sternocleidomastoidei and the infrahyoid muscles have been partly cut away, the mylohyoid and digastric divided, and the sternum, together with portions of the ribs and clavicle, removed. * = Commencement of right innominate vein. ** = Posterior root of external jugular vein. + = Oral mucous membrane. + * = Anastomosis between hypoglossal and lingual nerves.

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vein is usually larger than the right and frequently runs downward to the hemi-azygos vein as the *accessory hemi-azygos vein* (see page 81), although it still retains its connection with the left innominate vein. The right vein, after receiving the blood from the three upper intercostal spaces, usually empties into the right innominate vein, more rarely into the azygos vein.

6. The *vertebral vein* (Fig. 696) corresponds to the cervical, but not to the cerebral portion of the vertebral artery. Together with the vertebral artery it lies in the canal formed by the foramina transversaria of the upper six cervical vertebræ, and frequently passes also through the foramen transversarium of the seventh vertebra. It arises upon the posterior surface of the posterior arch of the atlas from the external vertebral venous plexuses, is reinforced by anastomoses with the occipital vein and by twigs from the intervertebral veins (see page 82), and empties either alone or together with the following vessel, into the posterior surface of the first portion of the innominate vein.

7. The *deep cervical vein* (Fig. 696) is larger than the vertebral and larger than the artery of the same name; it is, in fact, the largest vein in the nuchal region. It also arises from the external venous plexuses of the cervical vertebral column and from large anastomoses with the occipital vein (see page 91), and runs downward in the neck, together with the artery of the same name, between the semispinalis capitis and the semispinalis cervicis. It collects the venous blood from the nuchal musculature, passes forward with the deep cervical artery, and empties into the posterior surface of the commencement of the innominate vein, below the transverse process of the sixth cervical vertebra. Its orifice is usually guarded by a valve.

THE INTERNAL JUGULAR VEIN.

The *internal jugular vein* (Figs. 539, 551, 588, 693, 699, and 700) is a large vessel which collects the blood from the side of the head and neck, with the exception of those portions which are drained by the deep cervical veins (the deep cervical, vertebral, inferior thyreoids, see page 83) or by the external jugular passing to the innominate vein. Together with its tributaries it consequently corresponds in the main with the common carotid artery and its branches and also with the cerebral branches of the vertebral artery, since it receives all of the blood from the cranial cavity and from the brain.

The internal jugular vein commences in the jugular fossa of the temporal bone with a dilatation, the *superior bulb of the internal jugular vein*, and passes almost directly downward along the lateral wall of the pharynx together with the internal carotid artery, the caliber of the two vessels being approximately the same. The vein is at first behind and to the outer side of the artery, and then directly to the outer side, and the vagus nerve is situated between the artery and the vein. In this portion of its course the internal jugular corresponds almost exactly to the internal carotid artery, and not until it receives in the carotid fossa its largest tributary, the common

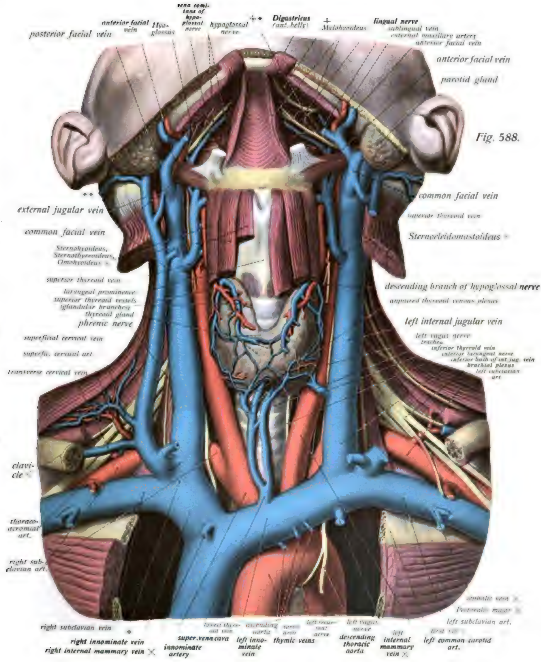
posterior facial vein
anterior facial vein
Hyoglossus
vena comitans of hypoglossal nerve
hypoglossal nerve
+ *
Digastricus (ant. belly)
+ Mylohyoideus
lingual nerve
sublingual vein
external maxillary artery
anterior facial vein
anterior facial vein
parotid gland
* *
external jugular vein
common facial vein
Sternohyoideus, Sternothyreoideus, Omohyoideus *
superior thyreoid vein
laryngeal prominence
superior thyreoid vessels (glandular branches)
thyreoid gland
phrenic nerve
superficial cervical vein
superfic. cervical art.
transverse cervical vein
common facial vein
superior thyreoid vein
Sternocleidomastoideus *
descending branch of hypoglossal nerve
unpaired thyreoid venous plexus
left internal jugular vein
left vagus nerve
trachea
inferior thyreoid vein
inferior laryngeal nerve
inferior bulb of int. jug. vein
brachial plexus
left subclavian art
clavicle ×
thoraco-acromial art.
right subclavian art.
cephalic vein ×
Pectoralis major ×
left subclavian art.
first rib ×
right subclavian vein
*
right innominate vein
right internal mammary vein ×
super. vena cava
innominate artery
lowest thyreoid vein
ascending aorta
aortic arch
left innominate vein
thymic veins
left recurrent nerve
left vagus nerve
descending thoracic aorta
left internal mammary vein ×
left common carotid art.

Fig. 588.

facial vein, which largely corresponds to the external carotid artery, does it become the great venous channel for the entire head and for a portion of the neck. It then lies lateral to the common carotid artery, to which it corresponds in this situation, and passes downward with this artery in a common vascular sheath as far as the venous angle (see page 83). Shortly before reaching the innominate vein it exhibits a second elongated dilatation about 1 cm. in length, the *inferior bulb of the internal jugular*, and at the lower portion of this dilatation there are one or two valves placed in the sagittal plane, these being the only valves possessed by the vein.

Among the chief tributaries of the internal jugular vein are:

THE SINUSES OF THE DURA MATER.

The *sinuses of the dura mater* (Figs. 589, 590, 679, 680, and 681) are peculiar blood channels, usually of great width, which have no valves, are completely devoid of muscular tissue, and are situated between the layers of the dura mater, from which they are separated only by the endothelial lining of the sinus wall. They receive the blood from the entire brain, from the eye, from the internal ear, and from the bones of the skull, and transmit it to the internal jugular vein, usually through the intervention of the transverse sinus. The following sinuses of the dura mater may be recognized:

1. The *transverse* (*lateral*) *sinus* (Figs. 589, 679, 680, 681, and 693) is paired and, as it receives the blood from almost all of the remaining sinuses, is by far the largest of the entire group. It commences in the region of the crucial eminence of the occipital bone, where it communicates with its fellow of the opposite side and takes up other sinuses to form the *confluens sinuum* (*torcular Herophili*), and in its subsequent course it follows the corresponding bony grooves—*i. e.*, it at first runs in the posterior margin of the tentorium in the transverse groove, then in the sigmoid groove, and finally passes through the posterior compartment of the jugular foramen into the superior bulb of the internal jugular vein. The right transverse sinus is usually larger than the left. A cross-section of the transverse portion of the sinus is approximately triangular, while that of the descending portion is more circular.

2. The *superior sagittal* (*longitudinal*) *sinus* (Figs. 589, 590, 679, 680, and 681) is the second largest sinus of the dura mater; it is unpaired and lies in the groove of the same name upon the inner surface of the cranial vault. It arises as a small vessel at the foramen cæcum, where it anastomoses with the nasal veins, and gradually increases in caliber as it receives the cerebral veins in its course toward the crucial eminence. Here it enters the confluens sinuum in such a manner that its blood passes almost wholly into the right transverse sinus or by bifurcation into both transverse sinuses. Its cross-section is triangular and its lumen is traversed by numerous trabeculæ of connective tissue.

3. The *inferior sagittal* (*longitudinal*) *sinus* (Fig. 589) is a smaller unpaired vessel situated in the lower margin of the falx cerebri and running parallel to the superior sagittal sinus. It receives but few cerebral veins, but takes up the veins of the falx cerebri itself, increasing in caliber as it passes backward and empties into the straight sinus.

4. The *straight sinus* (Fig. 589) is also unpaired and is situated in the posterior portion of the falx cerebri along the line where it is attached to the tentorium cerebelli. It pursues an almost horizontal course, terminating either in the common venous space (confluens sinuum)

FIG. 589.—The dura mater and its sinuses as seen from the left and from above.

The skull has been opened upon the left by a horizontal section extending almost to the median line and by a vertical section just to the left of the sagittal suture. A large part of the left and a small strip of the right tentorium have been removed.

in front of the crucial eminence, or more frequently in the commencement of the left transverse sinus, in which case the superior sagittal sinus empties into the right transverse.

5. The *occipital sinus* (Fig. 589) is a small, usually unpaired vessel of variable development which commences at the confluens sinuum, passes downward in the base of the falx cerebelli to the posterior circumference of the foramen magnum, and bifurcates in this situation to pass upon either side partly to the transverse sinus and partly to the internal vertebral venous plexuses of the upper cervical vertebræ.

6. The *cavernous sinus* (Figs. 589 and 679) is paired, situated at either side of the sella turcica, and covered by the portion of the dura mater which passes from the anterior clinoid process to the anterior portion of the line of origin of the tentorium from the superior border of the pyramid portion of the temporal bone. The sinus is a rather wide, irregular space, subdivided by numerous connective-tissue septa, and it contains the internal carotid artery with its sympathetic plexus and the abducens nerve. The cavernous sinuses of the two sides are connected with each other by transverse venous anastomoses, the *anterior* and *posterior intercavernous sinuses*, passing in front of and behind the hypophysis, and in this manner producing around the hypophysis the *circular sinus*.

7. The *sphenoparietal sinus* (Figs. 589 and 679) is a small paired vessel which commences upon the cerebral surface of the parietal bone and then runs along the posterior sharp margin of the lesser wing of the sphenoid to reach the cavernous sinus.

8. The *inferior petrosal sinus* (Fig. 589) is a paired vessel running in the groove of the same name along the petro-occipital fissure and connecting the posterior portion of the cavernous sinus with the superior bulb of the internal jugular vein. In its course it runs between the nerves which pass through the anterior compartment of the jugular foramen.

9. The *superior petrosal sinus* (Figs. 589, 679, and 680), also paired, runs in the groove of the same name upon the superior border of the pyramid of the temporal bone at the attached margin of the tentorium. It connects the posterior portion of the cavernous sinus with the transverse sinus, opening into the latter where it changes its direction from the horizontal to the vertical.

10. The *basilar plexus* (Fig. 679), formed by an extensive anastomosis of flat venous channels, is situated upon the clivus of the occipital bone. It is connected upon either side with the cavernous and inferior petrosal sinuses and with the neighboring blood-channels.

In addition to the cerebral veins and the veins of the orbit (see page 87) the sinuses of the dura mater also receive the following small veins.

(*a*) The *internal auditory veins* accompany the internal auditory artery. They originate in the internal ear, pass through the internal auditory meatus, and usually enter the transverse sinus.

(*d*) The *diploic veins*, flat, devoid of muscular tissue, and situated in the diploic canals, run from above downward, and are connected in a very variable manner by emissary veins with the sinuses of the dura mater and with the extracranial veins. Upon either side there may be recognized a *frontal diploic vein*, which empties into the superior

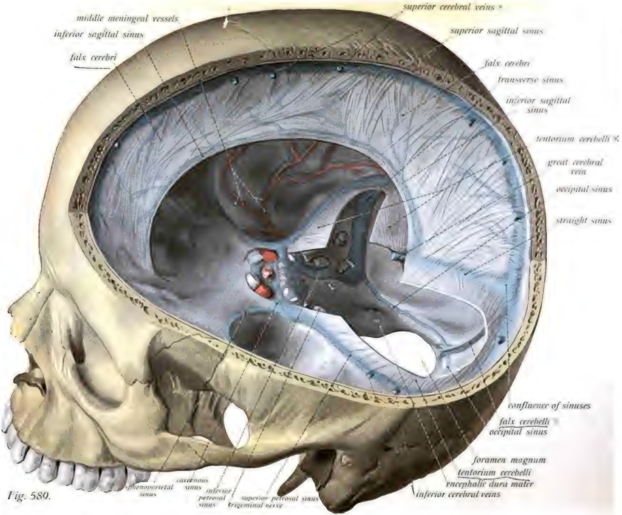
middle meningeal vessels
inferior sagittal sinus
falx cerebri
superior cerebral veins *
superior sagittal sinus
falx cerebri
transverse sinus
inferior sagittal sinus
tentorium cerebelli ×
great cerebral vein
occipital sinus
straight sinus
confluence of sinuses
falx cerebelli *
occipital sinus
foramen magnum
tentorium cerebelli
encephalic dura mater
inferior cerebral veins
sphenoparietal sinus
cavernous sinus
inferior petrosal sinus
superior petrosal sinus
trigeminal nerve

Fig. 580.

sagittal sinus and into the frontal vein; an *anterior temporal diploic vein*, which empties into the sphenoparietal sinus and into the deep temporal vein; a *posterior temporal diploic vein*, emptying through the parietal foramen into the superior sagittal sinus and through the mastoid foramen into the transverse sinus and the posterior auricular vein; and an *occipital diploic vein* which usually connects internally with the transverse sinus through an occipital foramen opening upon the internal occipital protuberance, and externally with the occipital veins.

The venous connections of the sinuses of the dura mater, of the diploic veins, and of the meningeal veins with the extracranial veins are known as *emissary veins*. The *parietal emissary vein* connects the superior sagittal sinus with the superficial veins of the skull; the *mastoid emissary vein* connects the transverse sinus with the occipital vein or one of the neighboring venous radicles of the external jugular vein; the *condyloid emissary vein* connects the transverse sinus and the external vertebral venous plexuses; the *occipital emissary vein* is inconstant, usually connecting only diploic veins with the confluens sinuum, more rarely the latter with the occipital veins.

Venous plexuses are also situated at the following openings in the skull, giving passage to vessels and nerves:

(*a*) The *internal carotid venous plexus* surrounds the internal carotid artery in its course through the carotid canal of the temporal bone. It forms a communication between the cavernous sinus and the internal jugular vein and also anastomoses with veins from the substance of the temporal bone.

(*b*) The *rete of the hypoglossal canal* is a small venous plexus surrounding the hypoglossal nerve, and is connected with the occipital sinus, the internal jugular vein, and the inferior petrosal sinus.

(*c*) The *rete of the foramen ovale* surrounds the mandibular nerve and forms a connection between the cavernous sinus and the pterygoid venous plexus.

The chief tributaries of the sinuses of the dura mater are the ophthalmic and cerebral veins.

THE OPHTHALMIC VEINS.

The valveless ophthalmic veins do not differ markedly in their ramifications from the course of the arteries. This statement applies to a certain degree to the larger superior ophthalmic vein, while the inferior ophthalmic vein transmits but a portion of its blood to the cranial cavity.

1. The *superior ophthalmic vein* (Fig. 679) commences anteriorly in the *nasofrontal vein*, which accompanies the frontal artery and anastomoses with the angular vein, which is the commencement of the anterior facial vein (see page 90). It enters the orbit above the medial palpebral ligament, runs backward below the trochlea of the obliquus superior in the upper portion of the medial wall of the orbit, passes outward above the optic nerve and below and to the outer side of the rectus superior, and reaches the cavernous sinus through the superior orbital fissure. During its course through the orbit it receives the *anterior* and *posterior ethmoidal veins*, the *anterior* and *posterior conjunctival veins*, *muscular veins* with their tributary *episcleral* and *anterior ciliary veins*, the *lachrymal vein*, the *vorticose veins* (see under Organs of Special Sense), the *posterior ciliary veins*, occasionally the *central vein of the retina*, which may also empty independently in the cavernous sinus, and finally the superior terminal branch or an anastomosis of the inferior ophthalmic vein.

2. The *inferior ophthalmic vein* does not pursue a constant course. It is situated in the lower portion of the orbit below the optic nerve where it arises from the veins of the lower lid and those of the lachrymal sac, and divides into two terminal branches, one of which either joins the superior ophthalmic vein or only anastomoses with it, emptying independently into the cav-

FIG. 590.—The arteries and veins of the brain as seen from above.

A piece of the dura mater has been left *in situ* along the superior sagittal sinus; the sinus itself has been opened longitudinally. * = Termination of veins in sinus.

ernous sinus, while the second terminal branch runs through the inferior orbital fissure to the facial anastomotic vein (see page 90) and to the pterygoid plexus.

THE CEREBRAL VEINS.

The cerebral veins pursue an essentially different course from that of the arteries, the two structures being partly associated only in the sulci of the surface of the cerebrum. While the chief ramifications of the arteries are located at the base of the brain, no large veins whatever are found in this situation; on the contrary, the great bulk of the cerebral veins, at least those of the cerebral hemispheres, empty superiorly into the superior sagittal sinus. The following valveless veins, usually arranged in groups, are recognizable:

1. The *superior cerebral veins* (Fig. 590) receive the blood from the greater portion of the surface (*i. e.*, of the gray cortex) of the cerebral hemispheres and form from twelve to fifteen small trunks, which empty into the superior sagittal sinus or into the expansions of this vessel, which are known as the lateral lacunæ. Some of the veins, especially the smaller ones coming from the region of the corpus callosum, terminate in the inferior sagittal sinus.

2. The *middle cerebral vein*, a larger vessel situated in the lateral cerebral fissure, anastomoses with the superior ophthalmic vein by the ophthalmomeningeal vein and empties into the cavernous or the sphenoparietal sinus.

3. The *inferior cerebral veins* (Figs. 589 and 679) collect the blood from the basal surface of the cerebral hemispheres and empty into the cavernous and transverse sinuses, partly also into the neighboring sinuses (petrosal, intercavernous).

4. The *great cerebral vein* (Figs. 549 and 638) is a short, large single vein running in the transverse cerebral fissure and terminating in the straight sinus, which forms its immediate continuation. It conducts the blood from the interior of the brain, particularly from the ventricular region, and is formed by the union of the two *internal cerebral veins*, which run in the tela chorioidea of the third ventricle. Each internal cerebral vein is formed in the region of the interventricular foramen by the junction of the *terminal* and *chorioid veins*. The terminal vein runs in the terminal stria (see under Brain), receives the *vein of the septum pellucidum*, and collects blood from the thalamus, the corpus striatum, and the corpus callosum. The chorioid vein drains the lateral chorioid plexus. Before their union to form the great cerebral vein, the internal cerebral veins also receive the veins of the chorioid plexus of the third ventricle, the veins of the lower surfaces of the corpus callosum and of the fornix, the veins of the pineal body, and the *basal vein* (vein of Rosenthal), an anastomotic vessel which ascends from the base of the brain along the crura cerebri.

5. The *superior cerebellar veins*, from the upper surface of the cerebellum, pass partly to the straight sinus, partly to the transverse sinus.

6. The *inferior cerebellar veins*, from the lower surfaces of the cerebellum, pons, and medulla oblongata, go chiefly to the inferior petrosal and transverse sinuses.

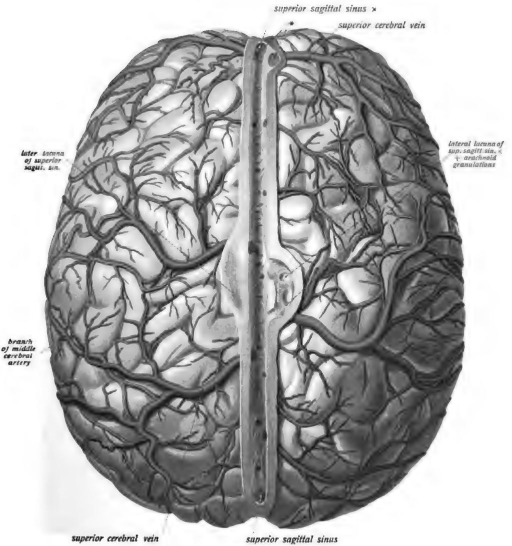
superior sagittal sinus ×
superior cerebral vein
later. lacuna of superior sagitt. sin.
lateral lacuna of sup. sagitt. sin. × + arachnoid granulations
branch of middle cerebral artery
superior cerebral vein
superior sagittal sinus

Fig. 590.

OTHER TRIBUTARIES OF THE UPPER PORTION OF THE INTERNAL JUGULAR VEIN.

In addition to the sinuses of the dura mater, the upper portion of the internal jugular vein receives the following tributaries:

1. The *vein of the cochlear canaliculus* runs from the cochlea through the canaliculus cochleæ to the superior bulb of the jugular vein.

2. The *pharyngeal veins* (Fig. 693) correspond approximately to the ascending pharyngeal artery. They arise from a wide-meshed *pharyngeal plexus*, situated upon the posterior and lateral walls of the pharynx, and also receive blood from the tuba auditiva (Eustachian tube), the palatal muscles, and from the vein of the pterygoid canal. They are valveless and usually empty singly, but in a very variable manner, into the internal jugular vein.

3. The *meningeal veins* (Figs. 589 and 679) empty partly into the sinuses of the dura mater. The paired middle meningeal veins which accompany the middle meningeal artery upon either side usually do not pass immediately to the internal jugular vein, but traverse the foramen spinosum to the pterygoid plexus, although they are also connected through the rete of the foramen ovale and by other anastomoses with the internal jugular vein.

4. The *lingual vein* (Figs. 588 and 695) drains approximately the same area as that supplied by the lingual artery. It empties into the common facial vein quite as frequently as directly into the internal jugular vein, and may also unite with one of the following veins. The lingual artery is usually accompanied throughout a considerable portion of its course by a double vein, while a single or double trunk of considerable size, the *vena comitans of the hypoglossal nerve*, runs with this structure below (lateral to) the hyoglossus muscle. All these veins usually unite before their termination to form a common trunk. The lingual vein, which is provided with valves throughout its entire extent, receives blood from the tongue, from the submaxillary and the sublingual glands, and from the muscles of the floor of the mouth. The special tributaries are: (*a*) The *sublingual vein*, which runs in the floor of the oral cavity and accompanies the submaxillary duct for some distance; (*b*) the *dorsal lingual veins*, from the mucous membrane of the dorsum of the tongue. The different veins of the tongue anastomose in a plexiform manner with each other and with the pharyngeal and other neighboring veins.

5. The *superior thyreoid veins* (Fig. 588) correspond in general to the superior thyreoid artery; they are double for either a portion or all of their course, and are provided with valves like the veins of the tongue. They collect blood from the upper portion of the thyreoid gland, from the upper portion of the larynx, and partly also from the contiguous musculature. They frequently empty into the common facial vein instead of directly into the internal jugular vein, and usually receive the *sternocleidomastoid* and *superior laryngeal veins*, although these vessels may also empty independently into the internal jugular.

In addition to these veins and disregarding an inferior thyreoid vein which occasionally empties into the inferior bulb, the internal jugular also receives as its largest tributary

THE COMMON FACIAL VEIN.

The *common facial vein* (Figs. 588, 591 to 593, and 699) is a short, thick trunk which corresponds generally, although not in detail, to the ramification of the common carotid artery. It is devoid of valves, arises below the angle of the mandible in the carotid fossa from the union

FIG. 591.—The nerves and vessels of the left side of the head (third layer).

The masseter has been divided in the middle and reflected, the temporal fascia thrown backward from the upper margin of the zygoma, and the parotid gland and facial nerve completely removed. Several facial muscles have been partly divided and the mandibular canal chiselled open for a certain distance. * = Anastomosis between supratrochlear and infratrochlear nerves. ** = Root of posterior facial vein from pterygoid plexus.

FIG. 592.—The nerves and vessels of the face (fourth layer, the deep facial veins).

The zygomatic arch has been removed, the temporalis with the mandibular coronoid process reflected upward, the mandibular neck excised, the external ear cut off, and the entire mandibular canal opened up. * = Anastomosis between supratrochlear and infratrochlear nerves. ** = Branches of buccinator nerve passing to mucous membrane of the cheek. + = Mylohyoid nerve. * on the vein = divided communication with external jugular vein.

FIG. 593.—The superficial veins of the neck and of the subclavicular fossa.

Upon the left side the greater portion of the sternocleidomastoideus has been removed, the clavicular portion of the pectoralis major incised, and the mylohyoid and anterior belly of the digastric divided. * = Communication between the external jugular and common facial veins. ** = Occipital root of external jugular vein. + = Perforating branches of the internal mammary vessels.

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of the anterior and posterior facial veins, and occasionally receives in a very variable manner one or more of the veins which usually empty directly into the internal jugular vein (the superior thyreoid, the lingual, and the pharyngeal veins). It is almost invariably connected with the external jugular vein (see page 91) at the anterior margin of the sternocleidomastoideus. It is superficially placed, being covered only by the platysma and the superficial layer of the cervical fascia, and passes downward and backward, crossing the external carotid artery obliquely. Its termination corresponds approximately to the level of the hyoid bone.

1. The *anterior facial vein* (Figs. 541, 542, 588, 591 to 593, 691, 692, 698 to 700) corresponds in general to the external maxillary (facial) artery, but in the orbital region it encroaches upon the territory of neighboring arteries (ophthalmic, superficial temporal). Upon the face it is situated some distance behind the external maxillary artery and pursues a less tortuous course than that vessel, which is accompanied by small veins. Its origin is the *angular vein*, which is situated at the inner canthus and upon the dorsum of the nose and is formed by the union of the *frontal* and *supra-orbital veins*, and an anastomosis with the *nasofrontal vein* (see page 87). In this situation the anterior facial vein also receives a number of smaller veins from the orbital region, namely, the *inferior palpebral veins*, the *external nasal veins*, and a portion of the *superior palpebral veins*. It furthermore receives a deep branch, known as the *facial anastomotic vein*, which comes from the temporal fossa, anastomoses with the pterygoid plexus and the inferior ophthalmic vein, and passes transversely across the buccinator to the anterior facial vein.

Other tributaries of the anterior facial vein are the *superior* and *inferior labial veins*, the *masseteric veins*, the *anterior parotid veins*, the *palatine vein*, coming from the tonsillar region, and finally, beneath the angle of the mandible, the large *submental vein*, which anastomoses with the sublingual vein and is connected with the anterior jugular vein (see below).

2. The *posterior facial* (*temporomaxillary*) *vein* (Figs. 539, 541, 542, 588, 591 to 593, 691, 692, 698 to 700) arises in front of the ear by the union of the temporal veins. The superficial temporal veins correspond to the branches of the artery of the same name; they do not, however, actually accompany these branches, but are situated at some distance from them and are connected by wide-meshed anastomoses with the occipital and the frontal veins. They unite to form a single trunk, which runs either in front of or behind the superficial temporal artery.

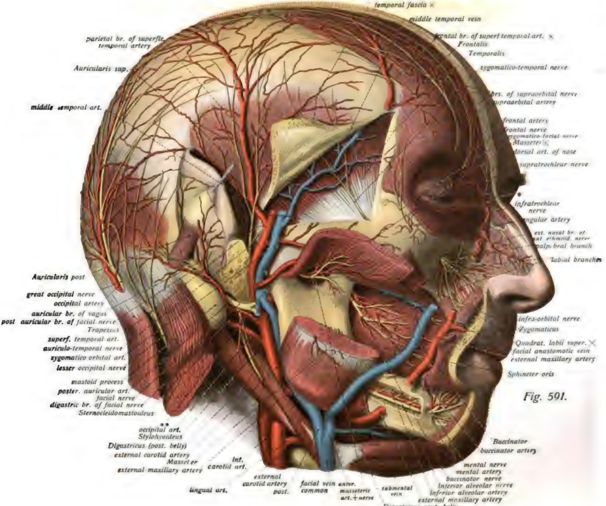

temporal fascia ×
middle temporal vein
parietal br. of superfic. temporal artery
frontal br. of superf temporal art. ×
Frontalis
Temporalis
Auricularis sup.
zygomatico-temporal nerve
brs. of supraorbital nerve
upraorbital artery
middle temporal art.
frontal artery
frontal nerve
ygomatico-facial nerve
Masseter ×
dorsal art. of nose
supratrochlear nerve
*
infratrochlear nerve
ngular artery
ext. nasal br. of
nt. ethmoid. nerve
palpebral branch
labial branches
Auricularis post
great occipital nerve
occipital artery
auricular br. of vagus
post auricular br. of facial nerve
Trapezius
superf. temporal art.
auriculo-temporal nerve
zygomatico orbital art.
lesser occipital nerve
infra-orbital nerve
Zygomaticus
Quadrat. labii super. ×
facial anastomotic vein
external maxillary artery
Sphincter oris
mastoid process
poster. auricular art.
facial nerve
digastric br. of facial nerve
Sternocleidomastoideus
** occipital art.
Stylohyoideus
Digastricus (post. belly)
external carotid artery
Masseter
external maxillary artery
int. carotid art.
Buccinator
buccinator artery
mental nerve
mental artery
buccinator nerve
Inferior alveolar nerve
Inferior alveolar artery
external maxillary artery
lingual art.
external carotid artery
post.
facial vein anter. common
masseteric art. + nerve
submental vein
Digastricus (ant. belly)

Fig. 591.

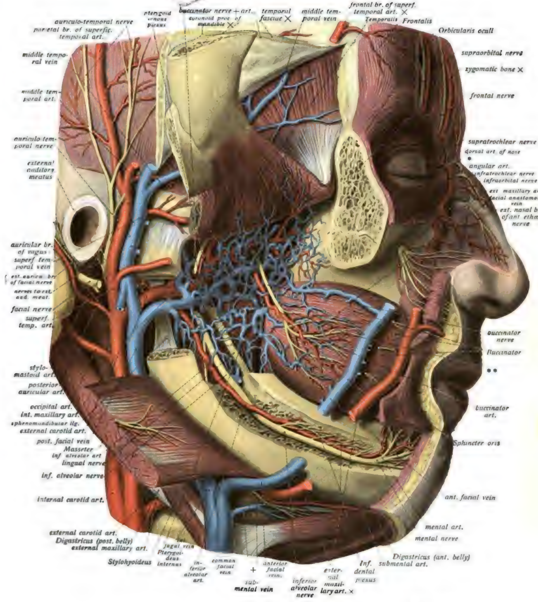
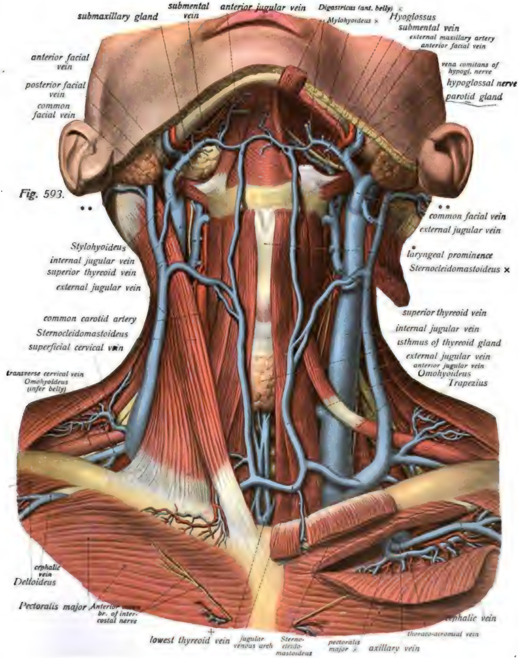

auriculo-temporal nerve
parietal br. of superfic. temporal art.
pterygoid venous plexus
buccinator nerve + art.
coronoid proc. of mandible ×
temporal fasciae ×
middle temporal vein
frontal br. of superf. temporal art. ×
Temporalis
Frontalis
Orbicularis oculi
supraorbital nerve
zygomatic bone ×
frontal nerve
middle temporal vein
middle temporal art.
auriculo temporal nerve
external auditory meatus
supratrochlear nerve
dorsal art. of nose
*
angular art.
infratrochlear nerve
infraorbital nerve
ext. maxillary art.
facial anastomotic vein
ext. nasal br. of ant. ethm. nerve
auricular br. of vagus
superf. temporal vein
ext. auricu. br. of facial nerve
nerves to ext. aud. meat.
facial nerve
superf. temp. art.
buccinator nerve
Buccinator
**
stylo-mastoid art.
posterior auricular art.
occipital art.
int. maxillary art.
sphenomandibular lig.
external carotid art.
post. facial vein
Masseter
inf. alveolar art.
lingual nerve
inf. alveolar nerve
buccinator art.
Sphincter oris
internal carotid art.
ant. facial vein
mental art.
mental nerve
external carotid art.
Digastricus (post. belly)
external maxillary art.
int. jugul. vein
Pterygoideus internus
Stylohyoideus
inferior alveolar art.
common facial vein
+
sub-mental vein
anterior facial vein
inferior alveolar nerve
external maxillary art. ×
Inf. dental plexus
Digastricus (ant. belly)
submental art.

Fig. 592.

Fig. 593.


submaxillary gland
submental vein
anterior jugular vein
Digastricus (ant. belly) ×
Mylohyoideus ×
Hyoglossus
submental vein
external maxillary artery
anterior facial vein
vena comitans of hypogl. nerve
hypoglossal nerve
parotid gland
anterior facial vein
posterior facial vein
common facial vein
common facial vein
external jugular vein
laryngeal prominence
Sternocleidomastoideus ×
Stylohyoideus
internal jugular vein
superior thyreoid vein
external jugular vein
common carotid artery
Sternocleidomastoideus
superficial cervical vein
superior thyreoid vein
internal jugular vein
isthmus of thyreoid gland
external jugular vein
anterior jugular vein
Omohyoideus
Trapezius
transverse cervical vein
Omohyoideus (infer belly)
cephalic vein
Deltoideus
Pectoralis major
Anterior [illegible] br. of intercostal nerve
cephalic vein
thoraco-acromial vein
lowest thyreoid vein
jugular venous arch
Sternocleidomastoideus
pectoralis major ×
axillary vein

The large ***middle temporal vein*** (Figs. 591 and 592), however, pursues a different course from that of the artery of the same name. It arises in the region of the lateral angle of the orbit, where it anastomoses with superficial veins, runs almost horizontally laterally and backward above the zygoma, between the temporal muscle and the temporal fascia, receiving branches from the muscle, perforates the temporal fascia immediately above the root of the zygoma, and joins the superficial temporal vein to form the posterior facial vein.

The posterior facial vein then runs downward with the external carotid artery, behind the ramus of the mandible and under cover of the parotid gland, and beneath the angle of the jaw it unites with the anterior facial vein to form the common facial vein. During its course the posterior facial vein receives the following branches: the ***anterior auricular veins***, from the outer surface of the pinna; the ***mandibular articular veins***, from the temporomaxillary articulation; the ***tympanic*** and ***stylomastoid veins***, from the tympanum; and the ***posterior parotid veins***, from the parotid gland. The ***transverse facial vein***, which is frequently partly or entirely double, also empties into the posterior facial vein, and the vein is also always connected by a transverse anastomosis with the upper portion of the external jugular vein. One of the largest tributaries of the common facial vein is the short venous trunk which derives its blood from the pterygoid plexus.

The ***pterygoid venous plexus*** (Fig. 592) is a strong, rather narrow-meshed venous network, the greater portion of which is situated between the temporalis and the pterygoideus externus. It extends into the pterygopalatine fossa and corresponds to the internal maxillary artery, which it surrounds. In addition to veins from the muscles of mastication, the pterygoid venous plexus receives the ***deep temporal veins*** corresponding to the arteries of the same name, the ***sphenopalatine vein*** which conveys blood from the nasal cavity, and the ***masseteric*** and ***inferior alveolar veins***, which accompany the similarly named arteries in a plexiform manner. It also receives the ***middle meningeal veins***, the ***rete of the foramen ovale***, anastomoses from the inferior ophthalmic vein, and the facial anastomotic vein. The majority of the branches of the plexus are provided with valves.

THE SUPERFICIAL (SUBCUTANEOUS) VEINS OF THE NECK.

The most marked of the superficial veins of the neck and the one which usually receives all of the remaining veins is:

1. *The External Jugular Vein* (Figs. 541, 542, 588, 593, 697, 698, and 714).—The relations and the caliber of this vessel are variable, but it is always smaller than the internal jugular. During the greater portion of its course it is situated upon the external surface of the sternocleidomastoideus, over which it passes almost vertically downward, covered only by the platysma and the superficial cervical fascia. It is formed below the ear and the parotid gland by the junction of an anterior branch, which is usually the larger and comes from the posterior facial vein (see above), with a posterior branch from behind the ear, which is practically the ***posterior auricular vein***, but which also received blood from some of the *occipital veins*.* At the posterior margin of the sternocleidomastoideus it sinks deeply into the supraclavicular fossa and usually receives one or more veins corresponding to the branches of the subclavian artery (the ***superficial cervical***,

* The greater portion of the blood of the occipital veins is poured into the deep cervical veins.

transverse scapular, and *transverse cervical veins*), either separately or as a common trunk, and after also receiving the anterior jugular vein, it finally empties into the venous angle or, more rarely, into the subclavian vein. It is provided with valves.

2. The *anterior jugular vein* (Figs. 593 and 698) arises in the submental region from anastomoses with the submental vein. It rests upon the lower surface of the mylohyoideus, passes downward close to the median line superficially in front of the sternohyoideus, communicates with neighboring veins and particularly with the external jugular by a transverse branch, and, passing deeply behind the anterior margin of the sternocleidomastoideus, usually terminates in the external jugular, although it occasionally empties into the subclavian or the internal jugular vein. It usually anastomoses with its fellow of the opposite side by a branch passing transversely above the manubrium of the sternum, the *jugular venous arch*. Sometimes the two anterior jugular veins are fused into a single vein situated in the middle line, the *median vein of the neck*.

THE SUBCLAVIAN VEIN.

The *subclavian vein* (Figs. 551, 587, 588, and 701), the immediate continuation of the axillary vein, does not correspond accurately to the artery, since the vertebral, the deep cervical, and the inferior thyreoid veins empty into the innominate and one or more of the veins of the supraclavicular fossa (see above) terminate in the external jugular. At the lower margin of the subclavius the subclavian vein continues onward from the axillary and together with the two jugulars (external and internal) forms the innominate vein. It lies in front of and below the subclavian artery, from which it is separated by the attachment of the scalenus anticus, and it describes a much flatter arch than that of this vessel. In front is situated the clavicular portion of the sternocleidomastoideus. It occasionally receives the transverse cervical or the transverse scapular vein (see above), but sometimes has no immediate tributaries. Throughout its course the vein is devoid of valves, but one of these structures is situated at its termination.

THE AXILLARY VEIN: THE VEINS OF THE UPPER EXTREMITY.

The veins of the upper extremity are the *deep veins*, which form the venæ comites of the arteries and are paired below the axillary, and the superficial or *subcutaneous veins*, for which there are no corresponding arteries. Both sets of veins are provided with valves, the deep veins, which are poor in muscular tissue, having a larger number than the superficial ones, which are provided with a strong muscular coat. The two sets of veins are connected throughout their course by numerous anastomoses, but the arrangement of the valves is such that blood can flow from the deeper into the superficial veins, but not in the opposite direction. All the veins of the upper extremity, both superficial and deep, are drained by the axillary vein.

The *axillary vein* (Figs. 552, 588, 593, and 594) arises at the lower margin of the axillary fossa by the union of the two brachial veins and traverses the fossa, lying medial and anterior to the artery. It is provided with valves, as are also its branches, and during its course it receives the following veins:

1. The *thoraco-acromial vein* (Figs. 539, 593, and 700) corresponds to the artery of the same name and frequently empties by a short trunk in common with the cephalic vein at the point where the axillary becomes the subclavian vein or even into the latter vessel.

2. The *cephalic vein* (see below).

3. The *lateral thoracic vein* (Figs. 552 and 594), a large vein upon the inner wall of the axillary fossa, corresponds only in part with the artery of the same name; it pursues a course parallel with the artery, but is usually of much larger size. It is of special importance on account of two of its anastomoses. The first of these is with a marked and frequently partly paired vein of the abdominal wall, the *thoraco-epigastric vein*, which comes from the region of the superficial epigastric vein and passes upward upon the lateral thoracic wall. This vessel may open separately into the axillary vein, in which case the lateral thoracic vein corresponds accurately to the lateral thoracic artery. The second anastomosis takes place either between the lateral thoracic vein itself or the thoraco-epigastric vein and the intercostal veins of the first to the seventh intercostal spaces, thus forming the *costo-axillary veins*. The veins of the mammary gland, which form the *mammillary venous plexus*, also send their blood through these veins to the axillary vein.

4. The *circumflex humeral*, the *circumflex scapular*, and the *subscapular veins* correspond to the similarly named branches of the axillary artery.

THE DEEP VEINS OF THE UPPER EXTREMITY.

The origins of the deep veins of the upper extremity are the small *proper volar digital* and *common volar digital veins*, which, like all the deep veins of the upper extremity, accompany the arteries of the same name. They are connected with the much larger superficial veins of the back of the hand by the *intercapitular veins* and form double *superficial* and *deep venous arches*, which accompany the similarly named arterial arches. The deep arch receives the *volar metacarpal veins*. The venous arches give origin to the *radial* and *ulnar veins*, which accompany the arteries of the same name as venæ comites, each of which is connected both with its fellow by numerous transverse anastomoses and also with the superficial veins. In the cubital fossa the radial and ulnar veins unite to form two *brachial veins*, which accompany the brachial artery; the medial brachial vein is usually larger than the lateral and receives the basilic vein (see page 94).

THE SUBCUTANEOUS VEINS OF THE UPPER EXTREMITY.

The superficial or subcutaneous veins of the upper extremity (Fig. 554) run between the skin and the deep fascia independently of the arrangement of the arteries and do not perforate the deep fascia until just before their termination in the deep veins. They originate in the *dorsal digital veins*, which are larger than the volar vessels, and receive the blood from the volar aspect of the finger tips, a condition of affairs exactly the reverse of what obtains in the case of the corresponding arteries. At the bases of the fingers they anastomose to form the *digital venous arches* (Fig. 713), which are convex anteriorly and frequently double. From these arches are given off the *dorsal metacarpal veins*, which are approximately parallel, irregularly arranged, and connected by numerous anastomoses. These dorsal metacarpal veins receive the intercapitular veins (see above) from the palm of the hand and form a wide-meshed network upon the dorsum, the *venous rete of the dorsum of the hand*.

From this rete are formed the two large subcutaneous veins of the upper extremity, the cephalic and the basilic veins.

1. The *cephalic vein* (Figs. 539, 551, 554, 588, 593, 595, 596, 699, 700, 710, 711, and 713)

FIG. 594.—The superficial layer of the vessels and nerves of the axilla.

The skin and fat have been reflected from the lower margin of the pectoralis major and the superficial fascia removed. * = Branches of the thoracodorsal vessels passing to the serratus anterior.

FIG. 595.—The cutaneous nerves and veins of the flexor surface of the upper arm.

FIG. 596.—The cutaneous nerves and veins of the flexor surface of the forearm.

* = Anastomosis between the lateral antibrachial cutaneous nerve and the superficial branch of the radial nerve. The skin and areolar tissue have been removed; the fascia has been retained.

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arises upon the back of the hand usually as a continuation of the first dorsal metacarpal vein, and in addition to anastomoses with the radial veins it receives veins from the palm. Running between the skin and the [deep] fascia, it is at first situated upon the outer portion of the dorsal surface of the forearm (Figs. 711 and 713); it then passes upon the volar surface of the forearm (Fig. 596) and runs toward the elbow, where it is connected with the basilic vein by the median cubital vein (see below). It passes through the lateral portion of the cubital fossa, runs in the lateral bicipital groove, and reaches the infraclavicular fossa by passing in the groove between the deltoid and the pectoralis major. In this situation it pierces the deep fascia, descends into the deltoideopectoral trigone, usually receives the thoraco-acromial vein, and empties into the axillary vein. From the cubital fossa to the wrist-joint the cephalic vein is accompanied by the lateral antibrachial cutaneous nerve and its branches. A small vein occasionally runs parallel with and lateral to the cephalic; it arises more to the ulnar side of the hand and is termed the *accessory cephalic vein*.

2. The *basilic vein* (Figs. 595 to 597, 711, and 713) arises upon the dorsum of the hand as a continuation of the fifth dorsal metacarpal vein. It receives the smaller veins from the ulnar border of the palm of the hand, passes from the dorsal to the volar surface of the forearm, and runs through the inner portion of the cubital fossa between the skin and the [deep] fascia to the upper arm, where it lies upon the inner border of the biceps. It is accompanied by the branches of the medial antibrachial cutaneous nerve. Below the middle of the upper arm the basilic vein pierces the brachial fascia, runs a short distance beneath this structure, and then passes into the medial brachial vein, which usually seems to be its direct continuation.

The cephalic and the basilic veins are usually united in the cubital fossa by an anastomosis situated in front of the lacertus fibrosus, the *median cubital vein* (Figs. 596 and 597), which is directed obliquely from above downward and from within outward. This vein usually carries a portion of the blood from the cephalic into the basilic vein, so that in the upper arm the latter vessel is larger than the former. The median cubital vein always anastomoses with the deep veins and occasionally it carries almost all the blood from the cephalic into the basilic vein, so that the former appears in the upper arm as a very small vessel. In extreme cases a cephalic vein may be entirely absent in the upper arm, being replaced by a small descending vein, in which case the basilic vein is unusually large and is termed the *capital vein*. Between the basilic and the cephalic veins and parallel to both there is a small vein upon the volar surface of the forearm, the *median antibrachial vein* (Figs. 596 and 597). When it is well developed it bifurcates in the cubital fossa into two branches, which pass to the cephalic and basilic veins respectively, and are known as the *median cephalic* and the *median basilic veins*. These veins then replace the median cubital vein.

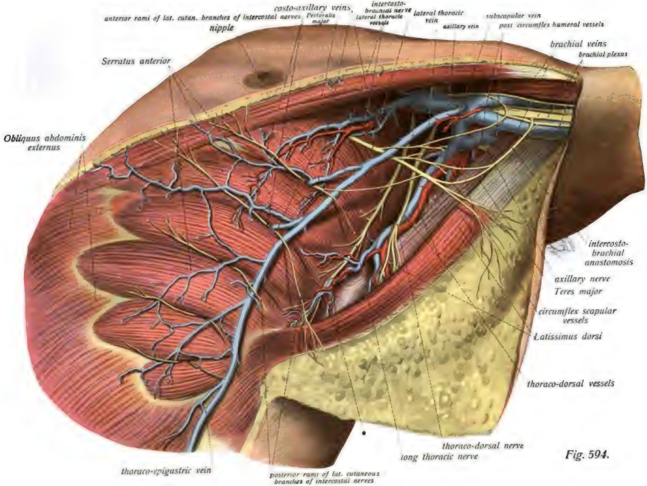
costo-axillary veins
intercosto-brachial nerve
lateral thoracic vein
subscapular vein
anterior rami of lat. cutan. branches of intercostal nerves
Pectoralis major
lateral thoracic vessels
axillary vein
post circumflex humeral vessels
nipple
brachial veins
brachial plexus
Serratus anterior
Obliquus abdominis externus
intercosto-brachial anastomosis
axillary nerve
Teres major
circumflex scapular vessels
Latissimus dorsi
thoraco-dorsal vessels
thoraco-dorsal nerve
long thoracic nerve
thoraco-epigastric vein
posterior rami of lat. cutaneous branches of intercostal nerves

Fig. 594.

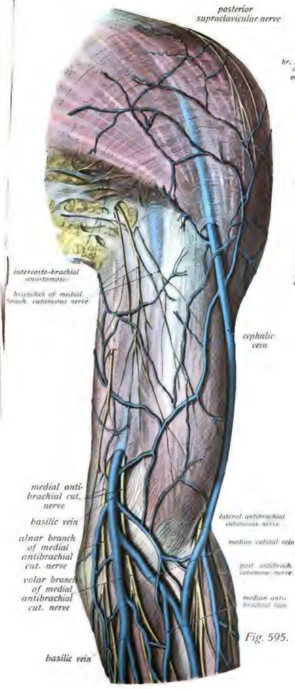

Fig. 595.

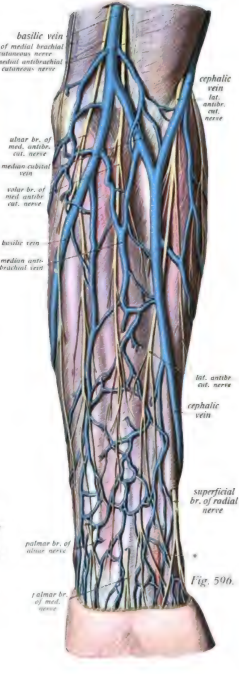

Fig. 596.

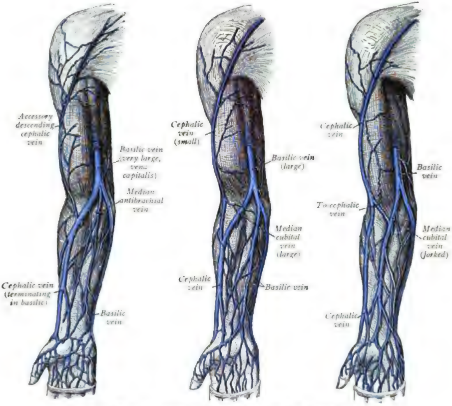

Fig. 597.—The most frequent variations in the veins of the forearm (schematic).

THE INFERIOR VENA CAVA.

The *inferior vena cava* (Figs. 389, 390, 413, and 716) is larger than the superior and is, in fact, the largest vein of the human body. The trunk, which is devoid of valves, arises by the union of the two common iliac veins in front of the right side of the fibrocartilage between the fourth and the fifth lumbar vertebræ and behind the right common iliac artery. It runs upward behind the parietal peritoneum on the right side of the bodies of the lumbar vertebræ, and is in close proximity to the abdominal aorta and is crossed by the right internal spermatic artery.

Up to the level of the pancreas it lies close to the right side of the aorta, but behind the pancreas it bends somewhat to the right and at the same time forward, and, passing in front of the right lumbar portion of the diaphragm, runs to the vena caval fossa of the liver, in which it is closely adherent to the substance of the liver (see page 247). From the fossa for the vena cava

the vein passes out of the abdominal cavity through the vena caval foramen of the diaphragm, and at once enters the pericardium, in which, invested by the visceral pericardium, it courses a distance of about 1 cm. before opening into the right atrium. Its orifice corresponds to the level of the eighth to the ninth thoracic vertebra.

Since the branches of the inferior vena cava arise partly from the abdominal viscera and partly from the abdominal wall, as well as through its two main roots, the common iliac veins, from both halves of the pelvis and both lower extremities, the branches are classified as the visceral and the parietal.

Visceral Branches of the Inferior Vena Cava.

The visceral branches of the inferior vena cava are the unpaired portal vein and the paired renal, suprarenal, and internal spermatic veins.

THE PORTAL VEIN.

The *portal system* (Figs. 389, 390, and 565 to 567) represents a special portion of the venous circulation. The portal vein itself carries to the liver venous blood from that part of the alimentary canal which is situated in the abdomen, that is to say, from the stomach and entire length of the small and large intestines [except from the lower part of the rectum.—Ed.], as well as from the pancreas and the spleen. In the liver its branches (the interlobular veins) divide and again become capillaries, from which are formed the branches to the vena cava, called hepatic veins. (For details of the more minute study of these vessels see Sobotta-Huber, *Histology*, Lehmann's *Medical Hand Atlas*, Vol. XXVI.) Consequently, it is the roots of the portal vein and not the vein itself that correspond to branches of the aorta.

The *portal vein* (Figs. 389 and 390) is a thick short stem, about 5 cm. long and without valves, which generally arises behind the pancreas by the junction of the superior mesenteric and splenic veins; the inferior mesenteric vein also sometimes taking part in its formation. It passes from the point of its formation between the laminæ of the hepatoduodenal ligament to the right and upward, thus coming to lie behind the hepatic artery and the ductus choledochus. With these vessels it enters the portal fissure, divides into a stronger, shorter right branch and a weaker but longer left branch, from both of which branches penetrate the liver tissue. The vessels carrying the portal blood from the liver are known as the *hepatic veins* and consist of a number of branches (*venæ hepaticæ minores*) which open into the inferior vena cava in the region of the caval fossa and also of a number of medium-sized stems and two or three larger ones (*venæ hepaticæ majores*), which open into the inferior vena cava where that vessel leaves the liver, shortly before piercing the diaphragm. The roots of the portal vein are:

1. The *superior mesenteric vein* (Figs. 565 and 566), the main root of the portal vein and apparently the prolongation of its principal stem, accompanies the superior mesenteric artery, to which it corresponds. It runs up with the artery, lying to the right of it, in the root of the mesentery, but only as far as its junction with the splenic vein. It collects the valveless venous branches corresponding to and accompanying the arterial branches to the intestine, that is to say, the *intestinal veins* (*jejunal* and *iliac*) from the small intestines, the *right* and *middle colic* and the *ileocolic veins* from the large intestines, the *pancreatic* and *pancreaticoduodenal veins*

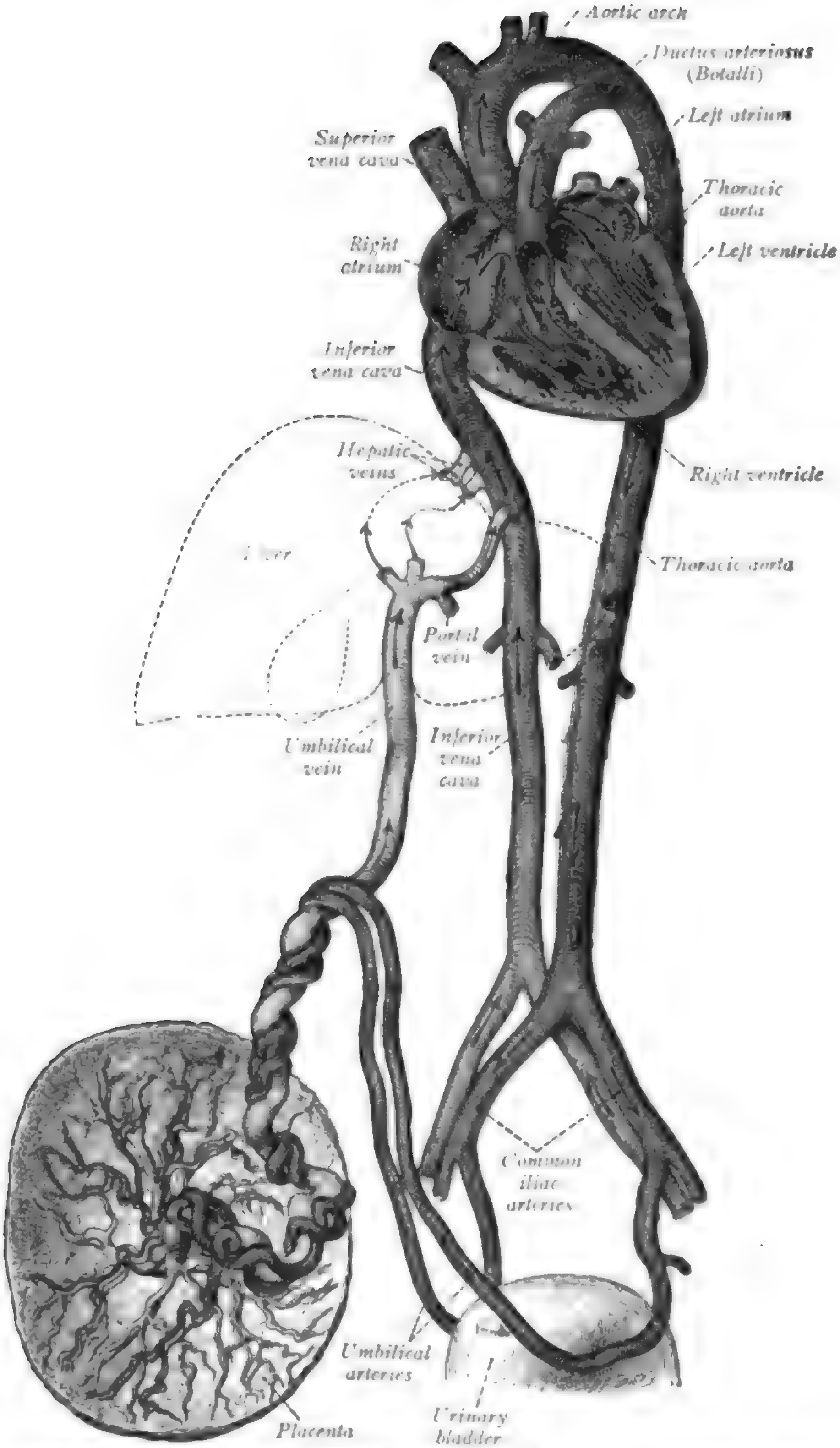

FIG. 508.—Plan of the fetal circulation. Vessels carrying arterial blood are colored red; those carrying venous blood, blue; those carrying mixed blood, violet. The blood stream from the umbilical vein through the liver is indicated by dotted lines.

from the pancreas and the duodenum, and the ***right gastro-epiploic vein*** from the stomach and omentum. Sometimes it also receives the inferior mesenteric vein.

2. The ***splenic vein*** (***vena lienalis***) (Figs. 565 and 567), the second main root of the portal vein, courses in company with the similarly named artery parallel with but behind the upper border of the pancreas, directly from left to right. It is situated below the artery, receives the splenic veins, the ***short gastric veins***, and the ***left gastro-epiploic vein***. Furthermore, in most cases it receives the inferior mesenteric vein.

3. The ***inferior mesenteric vein*** (Fig. 567) corresponds to the similarly named artery, with which it runs parallel, however, only in its peripheral portion. The main stem of the vein crosses the origin of the artery, goes up behind the pancreas, and opens usually into the splenic vein, more rarely into the superior mesenteric vein or at the point of junction of the two. It receives the ***superior hemorrhoidal vein***, the ***sigmoid veins***, and the ***left colic vein***, and, therefore, carries away the blood from the left part of the large intestines and rectum and, in the rectal wall, takes part in the formation of the hemorrhoidal plexus (see page 100).

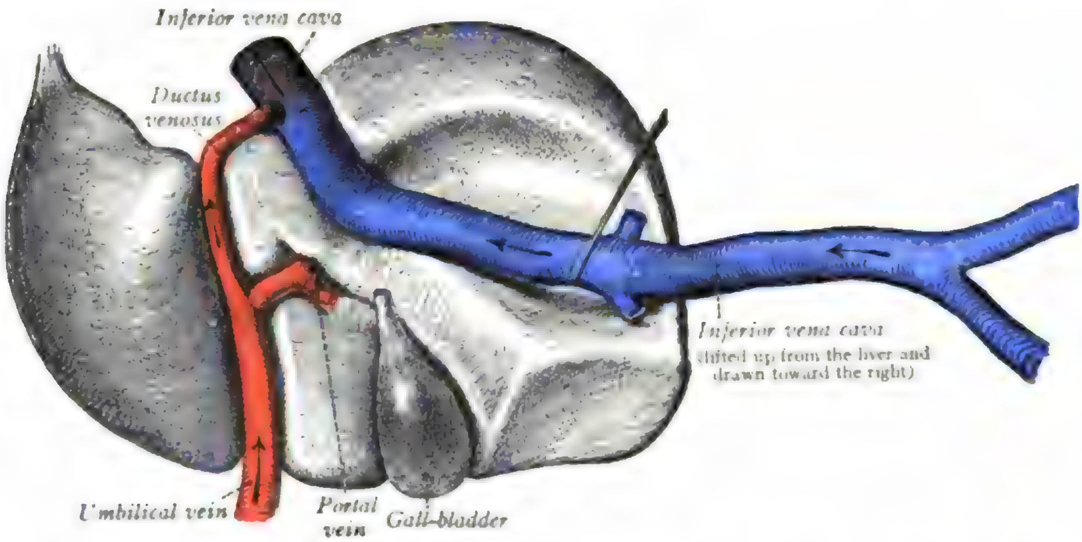

FIG. 599.—Plan of the circulation in the fetal liver. Vessels carrying arterial blood are colored red; those carrying venous blood, blue; those carrying mixed blood, violet.

4. The ***coronary vein of the stomach*** (***gastric vein***) (Fig. 564) corresponds to the two arteries bearing the same name, and runs along the lesser curvature of the stomach from left to right, receiving veins from the abdominal portion of the œsophagus, the cardia, and the anterior and posterior surfaces of the stomach. It anastomoses with the ***pyloric veins*** in the region of the pylorus and empties generally into the portal stem behind the superior part of the duodenum.

5. The ***cystic vein*** (Figs. 564 and 565) runs with the similarly named artery in the wall of the gall-bladder and empties either into the stem or, more often, into the right branch of the portal vein.

In the fetus the umbilical vein is connected to the portal vein until birth, after which it is obliterated and becomes the ligamentum teres of the liver (see Vol. II., pages 58 and 169). Its continuation to the vena cava inferior, known as

the *ductus venosus*, carries blood only until birth, whereupon it becomes the ligamentum ductus venosi. However, all through life small veins, known as the *para-umbilical veins* (Sappey), run along the ligamentum teres, arising from cutaneous veins in the region of the umbilicus and extending to the liver tissue (*accessory portal veins*). In addition, the portal system anastomoses through the hemorrhoidal plexus of the rectum with the middle and inferior hemorrhoidal veins, and along the abdominal portion of the œsophagus with the œsophageal veins, and thus with the azygos vein.

THE PAIRED VISCERAL BRANCHES OF THE INFERIOR VENA CAVA.

1. The *renal veins* (Figs. 413 and 716) open into the vena cava at right angles, at the level of the second lumbar vertebra. They accompany the similarly named arteries and are formed just in front of the hilus of the kidney by the union of three to five roots issuing from the renal sinus and the kidney tissue. The left vein is considerably longer than the right, since it must cross the median line before reaching the inferior vena cava. In so doing it passes close beneath the root of the superior mesenteric artery, and transversely across the abdominal aorta (more rarely behind the aorta), and it receives the left internal spermatic and the suprarenal veins. The renal veins may have valves at their mouths.

2. The *suprarenal veins* from the suprarenals. The left empties into the left renal vein.

3. The *internal spermatic veins* (Figs. 413, 490, 571, and 716) correspond to the similar arteries, and in the male are called testicular veins, in the female, ovarian veins. The left internal spermatic vein opens into the left renal vein.

The *testicular* (*spermatic*) *vein* arises as a thick, closely woven network, the *pampiniform plexus*, at the posterior border of the testes, passes upward in the spermatic cord still somewhat in the form of a plexus, supplies this cord by means of several branches, and finally forms a single stem in the abdominal cavity.

The *ovarian vein* (Fig. 570) also begins as the pampiniform plexus at the hilus of the ovary in the mesovarium and accompanies the artery, gradually losing in its course its plexiform arrangement. The veins of this plexus have their valves incompletely developed.

THE PARIETAL BRANCHES OF THE INFERIOR VENA CAVA.

In addition to the two common iliac veins the inferior vena cava receives the following parietal branches:

1. The *inferior phrenic veins* correspond to the similarly named arteries and open into the main stem just below the vena caval foramen.

2. The *lumbar veins I* to *IV* (Fig. 716) correspond to the arteries beside which they course, flowing in the same direction as the intercostal veins (see page 81). They are provided with valves, open posteriorly into the inferior vena cava, and are connected to one another by communicating ascending branches, called the *ascending lumbar veins*, which also bring about anastomoses with neighboring veins.

THE COMMON ILIAC VEIN.

The *common iliac vein* (Figs. 413 and 569) is a short, valveless stem, which corresponds to the similarly named artery on either side and is formed by the union of the hypogastric and external iliac veins. The right common iliac is shorter than the left, which crosses the anterior surface of the fifth sacral vertebra obliquely and receives an unpaired middle sacral vein,

corresponding to the similarly named artery. The common iliac vein lies at first behind its corresponding artery and then passes along its right side. The right vein does not have any branches, the left only the middle sacral vein, and, generally, an anastomosing branch to the ascending lumbar vein.

The *middle sacral vein* arises on the anterior surface of the sacrum from the *anterior sacral plexus*, which is formed by branches from the lateral sacral veins; it passes upward along the corresponding artery, at first as a double stem, later becoming single, and receives, as a rule, the lowest lumbar vein.

THE HYPOGASTRIC VEIN.

The *hypogastric (internal iliac) vein* (Figs. 569, 570, and 716) is a short, thick, valveless stem, which lies behind the corresponding artery. Its branches may be classified in a manner similar to the arterial branches into parietal and visceral. The former accompany their respective arteries and are, as a rule, double, while the latter form very fine, strong plexuses, which deviate considerably from the course of the arteries.

The Parietal Branches.—1. The *superior gluteal vein* accompanies the branches of the artery as two stems, which unite on entering the pelvis to form a single stem provided with valves.

2. The *inferior gluteal vein* (Figs. 569, 570, and 717) shows the same relations as the preceding one and corresponds to the artery even so far as to anastomose, as a rule, with the circumflex femoral and perforating veins.

3. The *obturator vein* corresponds to the artery; its branches are usually double and it anastomoses not only with the veins of the thigh but also with the external iliac.

4. The *lateral sacral veins*, generally double, accompany the corresponding artery and its branches, and arise on the anterior surface of the sacrum from the wide-meshed *anterior sacral plexus*, in the formation of which the middle sacral vein also takes part.

5. The *iliolumbar vein* (Fig. 716), whose branches are for the most part double, accompanies the corresponding artery and anastomoses with the fifth lumbar, the ascending lumbar, and the deep circumflex iliac veins.

The Visceral Branches.—1. The *internal pudendal vein* (Figs. 568 to 570 and 724) accompanies its corresponding artery partly as a double stem and partly as a network. It arises from the *deep vein of the penis (clitoris)*, the *urethral veins*, the *vein of the bulb of the urethra (vestibule)*, the *posterior scrotal (labial) veins*, and partly from the *inferior hemorrhoidal veins*.

2. The *pudendal plexus* (Figs. 482, 483, and 571) arises principally from the unpaired *dorsal vein of the penis* (in the female from the dorsal vein of the clitoris), which runs along the dorsal surface of the penis between the paired similarly named arteries. Its roots, partly divided into several branches which possess valves, are situated at the posterior border of the glans penis, and from here it passes, covered by the tendons of the ischiocavernosi, between the arcuate ligament of the pubis and the transverse ligament of the pelvis, to the plexus lying in front of the prostate gland and fundus of the urinary bladder. This plexus drains into the hypogastric veins either directly or by means of the veins of the bladder.

3. The *hemorrhoidal plexus* (Figs. 569 and 570) rests upon the posterior surface and the lateral portion of the wall of the rectum. From it arise the *superior hemorrhoidal vein*, which

passes to the portal (see page 98), the *middle hemorrhoidal vein*, which opens into the hypogastric, and the *inferior hemorrhoidal*, passing to the internal pudendal.

4. The *vesical plexus* (Figs. 569 and 570) is a wide-meshed network along the lateral and posterior surface of the bladder, which anastomoses with the pudendal plexus and opens into the hypogastric vein through several vesical veins.

5. The *uterovaginal plexus*, which occurs only in the female, is a wide-meshed network along the side of the vagina, and is continued as a fine-meshed strong plexus along the side of the cervix uteri and in the broad ligament close to its insertion into the body of the uterus. It is closely connected with the neighboring pelvic plexuses and drains into the hypogastric vein through the uterine vein.

THE EXTERNAL ILIAC VEIN.

The *external iliac vein* (Figs. 569, 570, and 716) is the second main root of the common iliac, and, as it is a direct continuation of the femoral vein, is the principal vein of the lower extremity. With the femoral and popliteal veins it forms a continuous vascular trunk which receives different names in different portions of its course. The portion above the inguinal ligament, which is destitute of valves, is called, like its corresponding artery, the external iliac vein. It is at first situated in the venous lacunæ to the median side of the artery and lateral to the crural canal and, on the left side, then passes up along the medial side of the artery and the medial border of the psoas major, while the right vein, which at first is also situated medial to the artery, in its upward course passes behind the artery before uniting with the hypogastric to form the common iliac vein. In the vascular lacunæ the external iliac vein receives the following afferents:

1. The *inferior (deep) epigastric vein* (Figs. 553, 569, 570, and 716) corresponds to the similarly named artery and has a simple trunk, although its branches are double. It possesses valves and anastomoses with the obturator vein behind the superior ramus of the pubic bone. Very often it receives the following vein shortly before its termination.

2. The *deep circumflex iliac vein* (Figs. 569, 570, and 716) corresponds to and accompanies the artery of the same name. It has valves, is generally double, and opens either separately or in conjunction with the preceding vein into the external iliac.

THE FEMORAL VEIN.

The *femoral vein* (Figs. 573 to 575) is a strong vessel which receives both superficial and deep veins, and is situated in the sheath of the corresponding artery, from which it is separated by a connective-tissue septum. It is formed in the region of the adductor hiatus by the popliteal vein, of which it is the direct continuation, and at first it lies behind and a little lateral to the artery, later passing exactly behind the artery to reach its medial side in the ileopectineal fossa. In the region of the fossa ovalis it is superficial, covered only by fat and the subinguinal lymph nodes. It contains a series of paired valves and its branches are partly deep and partly (sub)-cutaneous.

The Superficial Branches of the Femoral Vein.—All the superficial branches possess valves and open into the terminal portion of the femoral vein in the neighborhood of the fossa ovalis.

FIG. 600.—The superficial veins, arteries, and nerves of the anterior surface of the thigh.
FIG. 601.—The superficial veins, arteries, and nerves of the medial surface of the leg.
* = Connection with the deep veins. ** = Connection with the small saphenous vein.

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1. The *superficial epigastric vein* (Fig. 600) accompanies its artery, but is larger, and carries blood from the abdominal wall to the femoral vein. It anastomoses with the inferior epigastric, with the axillary through the *thoraco-epigastric vein*, and, through the para-umbilicals, with the portal.

2. The *external pudendal veins* (Fig. 600) correspond to their arteries and receive the anterior scrotal (labial) veins, as well as the subcutaneous dorsal vein of the penis (clitoris). They open either directly into the femoral vein in the region of the fossa ovalis or, as is often the case, into the long saphenous.

3. The *superficial circumflex iliac vein* corresponds to its artery. It is partly double and very often opens into the long saphenous vein.

4. The *long saphenous vein* (Figs. 317, 600, 601, 719, and 720) is the longest of all the cutaneous veins of the body, extending from the toes to just below the inguinal ligament. Its roots have their origin in the medial portion of the wide-meshed, superficial *venous rete of the dorsum of the foot*, which also gives rise to the other large vein of the leg, the small saphenous. As in the hand, so the dorsal veins of the toes, the *dorsal digital veins*, are larger than the plantar. They give off irregularly anastomosing branches, the *dorsal metatarsal veins*, which form an arched anastomosis, the *dorsal venous arch of the foot*, in the metacarpal region. The long saphenous vein arises from the medial portion of this arch and from the smaller plantar veins. Anastomosing frequently with the deep veins, it ascends in front of the medial malleolus up the medial surface of the leg, crosses behind the medial epicondyle of the femur, remaining superficial between skin and fascia, and upon the thigh it gradually turns from the medial to the anterior surface and enters the femoral vein superior to the margin of the lateral falciform ligament in the region of the fossa ovalis (see Vol. I., page 232).

Throughout its course it is subcutaneous and gradually increases in size while ascending, collecting numerous cutaneous veins from the medial and posterior surfaces of the leg, and from the anterior and, to a certain extent, the posterior surface of the thigh. It forms several anastomoses with the small saphenous vein and is accompanied in its course along the leg and foot by branches of the saphenous nerve. Occasionally there occurs in the thigh a rather independent parallel vein, the *accessory saphenous vein*, which collects the cutaneous veins from the median and posterior surface of the thigh and unites with the long saphenous in the region of the fossa ovalis.

The Deep Branches of the Femoral Vein.—The deep veins of the thigh (Figs. 573 to 575) are double stems which accompany the corresponding arterial branches. In addition to some small veins accompanying the femoral artery, there are the *deep femoral veins*, which generally open into the femoral vein as a single short stem, and are formed by the (double) *medial femoral circumflex*, the *lateral femoral circumflex*, and the *perforating veins*.

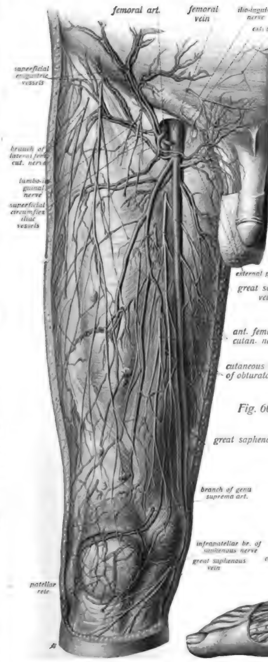

Fig. 600.

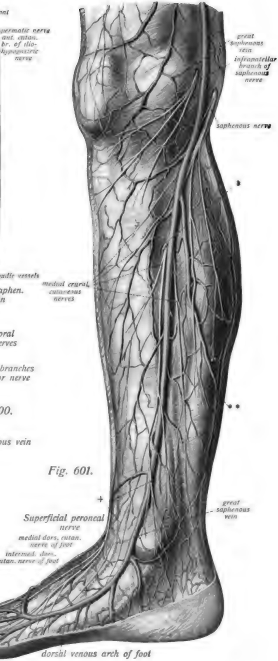

Fig. 601.

THE POPLITEAL VEIN.

The *popliteal vein* (Figs. 579, 580, and 718) accompanies its artery lying behind and somewhat lateral to it in the popliteal fossa. In the lower portion of the popliteal space it may be double, while above it is, as a rule, single like the femoral vein. In addition to its deep roots, the tibial veins, it receives one of the two large superficial veins of the leg, namely:

1. *The Small Saphenous Vein* (Figs. 576 and 718 to 720).—It arises from the lateral portion of the venous rete and the venous arch (see above) of the dorsum of the foot, anastomosing also with the deep plantar veins. From here it courses, in company with the branches of the sural nerve, behind the lateral malleolus and, resting upon the lateral border of the tendon of Achilles, reaches the middle of the calf, where, below the popliteal region, it pierces the fascia and reaches the popliteal fossa by passing through the groove between the two heads of the gastrocnemius. Here it usually divides into two branches, the main branch uniting with the popliteal vein, while the other passes toward the thigh to unite with the deep veins of its posterior surface, especially with the lower perforating veins. By a superficial side branch, the *femoropopliteal vein*, this branch is connected with the long saphenous vein. In addition to its anastomoses with the deep veins of the leg, the small saphenous vein also receives the superficial veins of the lateral and posterior surfaces of the crus.

2. The deep roots of the popliteal vein (Fig. 721) are all double veins accompanying arteries. They lie in the sole of the foot, where they form an arrangement similar to that occurring in the palm of the hand.* The *plantar digital veins* form the *plantar metatarsal veins* and the *deep plantar venous arch*, from which the *lateral plantar veins* arise; these, like the weaker *medial plantar veins*, corresponding to the respective arteries and forming the *posterior tibial veins*, which receive the peroneal veins. They then unite with the *anterior tibial veins*, which arise from the *dorsal metatarsal veins*, to form the popliteal veins.

THE LYMPHATIC SYSTEM.

In the human body the lymphatic system appears to be an appendage to the vascular system and especially to the veins into which the large lymph vessels empty. It differs from the vascular system in the first place by starting with capillaries, the lymph capillaries, which form the origin of the entire lymphatic system and contribute a peripheral network extending to almost all parts of the body. These capillaries are not interposed between the ends of larger vessels as are those of the vascular system, but form the beginning (or end) of the entire system. From the lymph capillaries usually very fine and thin-walled *lymphatic vessels* arise, which are for the most part situated superficially and are then called *superficial lymphatic vessels*, while a smaller number of deep vessels, the *deep lymphatic vessels*, accompany the large blood-vessels.

The *lymphatic vessels* are much thinner walled and much weaker than the blood-vessels and, with the exception of the lymph capillaries, have but little inclination to anastomosis. In addition, they pursue a relatively straight and extended course; if they unite it is at a sharp angle into vessels which are but little larger than themselves, and they may run long distances parallel with others,

* In the sole of the foot there is also a fine superficial venous network, the *plantar venous rete*, and furthermore, *intercapitular veins* allow of the passage of blood from the plantar veins into the superficial venous rete of the dorsum of the foot, just as in the hand.

at least in the case of the superficial lymphatic vessels. Some of the deeper vessels are of especial size and are called *lymphatic trunks*, and all have valves which are comparatively close together.

A further peculiarity of the lymphatic system which distinguishes it from the blood-vascular system is presented in the *lymph glands* or *nodes* which are interposed in the lymphatic circulation. The lymph passing from the lymph capillaries to the lymph vessels never flows directly into the venous system, but always traverses several lymph nodes on its way. These nodes (for the finer structure see Sobotta-Huber's *Histology*, Lehmann's *Medical Hand Atlas*, Vol. XXVI.) rarely occur singly, but are arranged in smaller or larger groups in definite regions of the body. They are most numerous in the trunk or at the points of attachment of extremities to the trunk, but they occur but rarely in the extremities themselves. Each node receives as afferent vessels either peripheral lymph vessels or vessels from neighboring nodes lying nearer the periphery, and slightly larger efferent vessels leave the node to pass to a more centrally located node and to finally enter a trunk. In this manner, through the interposition of lymph nodes in the roots of main lymph stems, *lymphatic plexuses* arise, neighboring lymph nodes being usually connected by several, generally short, vessels. The size of the nodes varies considerably, the smaller lying generally nearer the periphery, while the larger ones are nearer the center of the body. However, in certain peripheral regions quite large nodes may occur, the largest (normal) nodes having a diameter of scarcely 3 cm., while the smaller ones often are only one-tenth this size.

The Large Lymphatic Stems.

The distribution of the large lymphatic stems is such that each extremity, each side of the head and neck, and the abdominal viscera have a special stem through which the lymph flows. There are thus seven large lymphatic stems, three of which unite to form a common trunk, the thoracic duct, the largest lymph vessel in the body, which generally, before emptying into the venous system, receives two other stems, while the remaining two usually form an independent stem of their own. There are in addition, however, two smaller stems, varying somewhat in their behavior, which drain the chest wall and the thoracic viscera.

I. THE THORACIC DUCT.

The *thoracic duct* (Figs. 538, 587, 602, and 605) is generally formed about the level of the second lumbar vertebra by the union of the two lumbar trunks with the intestinal trunk to form a rather long irregular enlargement, the *cisterna* (*receptaculum*) *chyli*. From this point the thoracic duct passes as a thin-walled, irregular, occasionally even plexiform stem, behind and to the right of the aorta, through the hiatus aorticus, and then, resting upon the anterior surface of the thoracic vertebræ, it ascends between the thoracic aorta and azygos vein to the level of the fourth thoracic vertebra, where it bends toward the left, passing behind the œsophagus, and emerges between the left subclavian and the left common carotid arteries through the superior thoracic aperture into the left supraclavicular fossa. From here it curves forward and downward over the arch of the subclavian artery and opens into the left angulus venosus (see page 83) or (rarely) into either of the veins forming the angle.

The roots of the thoracic duct are:

1. The *right* and *left lumbar trunks* (Figs. 602 and 605) are two plexiform stems which have

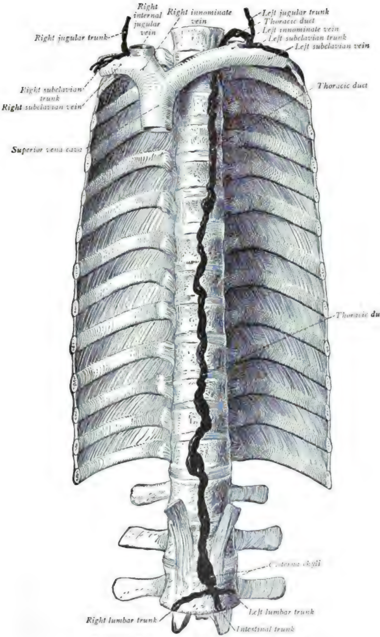

Fig. 602.—Plan of the thoracic and right lymphatic ducts.

FIG. 603.—The lymph nodes of the right side of the head and neck of a child.

Portions of the sternocleidomastoideus, omohyoideus, pectoralis major, and pectoralis minor have been removed in order to show the deeper glands. The platysma has been removed.

FIG. 604.—The superficial lymphatic vessels and lymph nodes of the arm, thoracic wall, and axilla.

The lymphatic vessels have been injected with India ink.

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their origins in the lumbar plexuses (see below), and conduct the lymph from the lower extremities and pelvis.

2. The *intestinal trunk* (Figs. 602 and 605), an unpaired stem draining the mesenteric lymph nodes and through them the abdominal viscera and especially the intestine.

As it ascends in front of the spinal column the thoracic duct receives the lymphatic vessels of the thoracic walls which accompany the intercostal blood-vessels, and in the neck, the lymphatic stems from the left upper extremity and from the left side of the head and neck enter the terminal portion of the duct, either through a single short stem, the *left lymphatic trunk*, or (more frequently) the two open separately as the *left jugular* and the *left subclavian trunks* into the terminal portion of the duct, or the left jugular trunk may open into the terminal portion of the internal jugular vein. In addition, the lymph from the left thoracic viscera and wall empties into the thoracic duct through the *left bronchomediastinal trunk*.

II. THE RIGHT LYMPHATIC DUCT.

The lymph which is not conveyed by the thoracic duct, that is to say, that from the right half of the upper part of the body, empties into the right angulus venosus or the right innominate vein through a stem, the *right lymphatic duct* (Fig. 602), which is short, usually only about 1 cm. in length. Its roots are:

1. The *right jugular trunk*, which coming from the deep cervical lymphatic nodes drains the right side of the head and neck.

2. The *right subclavian trunk*, which arises from the axillary lymph nodes and carries the lymph of the right upper extremity.

3. The *right bronchomediastinal trunk*, formed from the efferent vessels of the bronchial and mediastinal nodes, collects the lymph of the right thoracic wall, the right lung, the heart, the œsophagus, and a portion of the liver.

THE LYMPHATIC NODES AND LYMPHATIC PLEXUSES.

I. LYMPHATIC NODES AND PLEXUSES OF NECK AND HEAD.

1. The *posterior auricular nodes* (Fig. 603) are two or three in number and are generally very small, lying upon the tendon of insertion of the sternocleidomastoid behind the ear. They drain the posterior auricular region.

2. The *occipital nodes* (Fig. 603), not constant, are one or two in number lying upon the insertion of the trapezius. They drain the occipital region and send their efferent vessels to the superficial cervical nodes.

3. The *anterior auricular nodes* (Fig. 603) are also small, but more numerous (three or four).

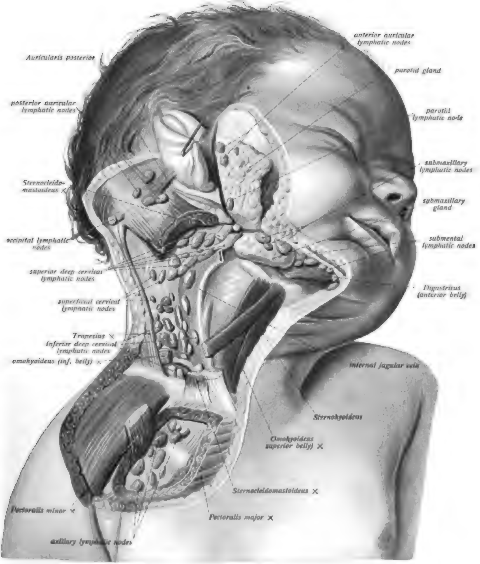
anterior auricular lymphatic nodes
Auricularis posterior
parotid gland
posterior auricular lymphatic nodes
parotid lymphatic node
submaxillary lymphatic nodes
Sternocleidomastoideus ×
submaxillary gland
occipital lymphatic nodes
submental lymphatic nodes
superior deep cervical lymphatic nodes
Digastricus (anterior belly)
superficial cervical lymphatic nodes
Trapezius ×
inferior deep cervical lymphatic nodes
omohyoideus (inf. belly) ×
internal jugular vein
Sternohyoideus
Omohyoideus superior belly) ×
Sternocleidomastoideus ×
Pectoralis minor ×
Pectoralis major ×
axillary lymphatic nodes

Fig. 603.

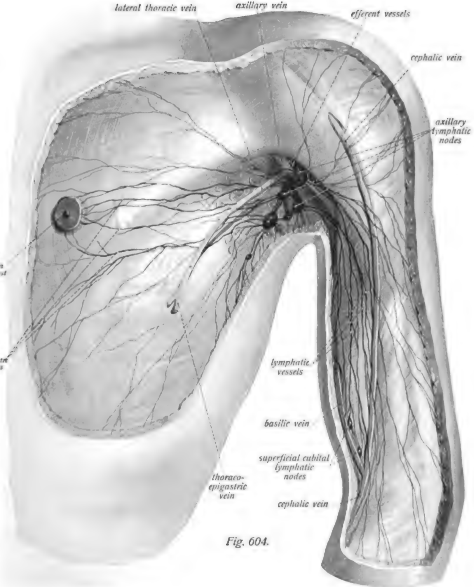
lateral thoracic vein
axillary vein
efferent vessels
cephalic vein
axillary lymphatic nodes
papilla of breast
lymphatic vessels
lymphatic vessels
basilic vein
superficial cubital lymphatic nodes
thoraco-epigastric vein
cephalic vein

Fig. 604.

Their location is superficial, anterior to the ear, upon the parotid gland, and they drain the temporal region, their efferents passing either to the superficial cervical or the submaxillary nodes.

4. The *parotid nodes* (Fig. 603) are imbedded in the substance of the parotid gland and receive lymph from the gland and also from the eyelids and the external ear. Their efferents pass to the superficial cervical or superior deep cervical nodes.

5. The *deep facial nodes* are situated upon the buccinator muscle and on the lateral wall of the pharynx. They drain the deep lymph vessels of the face (orbit, nasal cavity, palate, etc.) and come into relation with the superior deep cervical nodes, there being no distinct line of separation between the two groups.

6. The *submaxillary nodes* (Fig. 603) are eight or more in number and are rather large; they lie in the triangle between the body of the mandible and the digastric muscle, some, known as the *submental* nodes, resting upon the under surface of the mylohyoid muscle. They drain the anterior part of the face and chin and empty into the superficial and deep cervical nodes.

7. The *lingual nodes* are very few in number (frequently only one) and are inconstant. When present they are situated upon the hyoglossus muscle and drain only a portion of the tongue, the majority of the lymphatics of this organ passing directly to the submental, submaxillary, and superior deep cervical nodes.

8. The *superficial cervical nodes* (Fig. 603) are found along the side of the neck, occurring partly under cover of the platysma upon the lateral surface of the sternocleidomastoid muscle, along the posterior border of that muscle, at the inferior border of the parotid gland, and partly also in the anterior neck region. They receive lymphatics directly from the neighboring regions, but for the most part their tributaries are efferent vessels from the occipital, posterior auricular, parotid, anterior auricular, and submaxillary nodes. Their efferent vessels terminate in the deep cervical nodes.

9. The *superior deep cervical nodes* (Fig. 603) are ten to fifteen rather large nodes situated in the carotid fossa along the internal jugular vein and at the bifurcation of the common carotid. They collect lymph from the cranium and receive the efferent vessels of the deep facial, parotid, and submaxillary nodes and also lymphatics from the pharynx, the tympanic cavity, the tuba auditiva (Eustachian tube), the inner ear, a part of the thyreoid gland, and the larynx. Their efferent vessels pass to the inferior deep cervical nodes.

10. The *inferior deep cervical nodes* (Fig. 603) occur along the lower part of the internal jugular vein and in the supraclavicular fossa. They also are of considerable size, and since they receive the efferents of the superior nodes and also independent lymphatics from the lower portion of the larynx, trachea, and œsophagus, they practically receive the entire drainage of the head and neck. Together with the superficial and superior deep cervical nodes they form the *jugular plexus*, consisting of lymphatics (afferent and efferent vessels) and numerous interposed lymphatic nodes, which extends along the internal jugular vein and terminates below in the jugular trunk.

II. LYMPHATIC NODES AND PLEXUSES OF THE UPPER EXTREMITY.

The most peripheral nodes of the upper extremity are those of the elbow joint.

1. The *superficial cubital nodes* are (one to two) small nodes situated along the basilic vein in the region of the cubital fossa. They receive some of the numerous superficial lymphatics

of the forearm, and their efferent vessels pass upward in the upper arm to the axillary nodes.

2. The *deep cubital nodes* are located deeply in the cubital fossa along the brachial artery and vein and receive deep lymphatics of the forearm.

3. The *axillary nodes* (Figs. 603 and 604) are numerous medium-sized nodes situated, some rather superficially and others more deeply, in the fatty tissue of the axillary fossa along the axillary vein and artery. They receive practically all the lymph of the upper extremity and also that of the scapular region, the nape of the neck, the anterior thoracic wall and mammary gland, and part of the anterior and lateral abdominal walls, thus forming a center for lymph vessels from an extensive territory. Most of the lymphatics of the regions mentioned open directly as afferent vessels into the axillary nodes, only some of them passing through the cubital nodes or the smaller nodes mentioned below. The superficial and deep nodes are intimately connected and thus form the *axillary plexus*, consisting of a loose network of lymphatics and nodes, which on the left side is connected with the thoracic duct through the subclavian trunk and on the right side with the right lymphatic duct.

In addition, within the limits of the upper extremity and thoracic walls, the following two inconstant sets of glands occur:

4. The *subscapular nodes*, situated along the artery of the same name, are connected with the deep axillary nodes.

5. The *pectoral nodes*, one to two small nodes upon the external surface of the pectoralis major.

[Although the axillary nodes are properly regarded as forming a single group, yet for convenience they may be divided into a series of subordinate groups according to their position and connections. These subgroups are: (1) The *brachial nodes*, a series of large nodes situated along the course of the axillary vein and receiving the majority of the vessels from the arm; (2) the *anterior pectoral nodes*, two or three usually small nodes over the second and third intercostal spaces beneath the lower border of the pectoralis major. They receive afferents from the anterior surface of the thorax and from the mammary gland; (3) the *inferior pectoral nodes*, two or three small nodes situated posterior to the long thoracic vessels and receiving afferents from the lateral wall of the thorax; (4) the *subscapular nodes*, situated along the subscapular vessels and draining the scapular region; (5) the *intermediate nodes*, imbedded in the adipose tissue of the axillary fossa and receiving afferents from all the subgroups already mentioned; and (6) the *subclavicular nodes*, consisting of six to twelve nodes situated at the apex of the axillary fossa. They receive afferents from all the remaining subgroups and their efferents unite to form the subclavian trunk.—Ed.]

III. THE LYMPHATIC NODES AND PLEXUSES OF THE THORAX.

The thoracic nodes may be divided into those of the thoracic viscera and those of the thoracic wall. The first are:

1. The *bronchial nodes* (Figs. 447, 448, 455, and 459) are divided into the *pulmonary nodes*, which are the smaller ones lying within the lung tissue; the *bronchial nodes* proper, which are twenty to thirty larger ones lying at the hilus of the lung, along the bronchi and at the bifurcation of the trachea; and the very small *tracheal nodes*, situated along the trachea. These nodes are often black in color in the adult on account of the coal-dust and other impurities of the atmosphere inspired during life being conducted from the alveoli of the lung to these nodes by the action of

leukocytes. The several groups of bronchial nodes receive the numerous lymphatics lying on the surface of the lung beneath the pleura, as well as deeper vessels, which accompany the branches of the bronchi. In addition, the upper nodes of the group receive lymph from the lower part of the trachea and the lower ones receive it from the heart. The efferent vessels form the principal root of the bronchomediastinal trunk.

The following groups drain the thoracic wall:

2. The *intercostal nodes* are very small nodes situated near the heads of the ribs. They drain the intercostal spaces and their efferents generally pass directly to the thoracic duct, those of the right side also passing to the right bronchomediastinal trunk.

3. The *sternal nodes* are very small and are situated along the course of the internal mammary vessels, forming the *mammary plexus* and draining the anterior portions of the intercostal spaces and also partly the mammary gland and diaphragm. The efferents unite with those from the following nodes.

4. The *anterior mediastinal nodes* are medium-sized nodes directly connected with the preceding, behind which they are situated. They are found in the superior and sometimes also in the inferior portion of the anterior mediastinal cavity and receive lymphatics from the diaphragm, the liver, most of the vessels from the heart, and those from the pericardium and thymus gland. Their efferents unite with those from the bronchial nodes to form the bronchomediastinal trunk.

5. The *posterior mediastinal nodes* are a few small nodes lying along the thoracic aorta and receiving lymphatics from the neighboring tissues.

IV. THE LYMPHATIC NODES AND PLEXUSES OF THE ABDOMEN.

The abdomen contains a larger number of lymphatic nodes than any other region of the body, the mesentery of the small intestine being especially rich in them. The following groups may be distinguished:

1. The *mesenteric nodes* (Fig. 606) form the largest group in the body. They number over one hundred and are arranged in the mesentery in several rows, the smallest and most scattered nodes lying nearest the intestine. As the root of the mesentery is approached the nodes become larger and more numerous and the chain is completed at the root of the mesentery by some very large and closely set nodes. The afferents of these nodes have their origin in the intestinal wall and are called chyle vessels, since they contain during digestion food substances absorbed from the intestinal wall, the lymph thereby acquiring a milky-white color and being known as *chyle*. As a rule the lymphatics coming from the intestinal wall enter the first row of nodes as afferent vessels, the efferents of these nodes serve as afferents for the next row, and so on, until finally the last efferent vessels form the intestinal trunk, which is generally composed of several parallel stems.

2. The *mesocolic nodes* are smaller and less numerous than the mesenteric and are, as a rule, arranged in a single row. They receive the lymphatics of the large intestine and conduct the lymph to the intestinal trunk.

3. The *cœliac nodes* are fifteen to twenty in number and lie behind the stomach, pancreas, and duodenum in close proximity to the largest mesenteric nodes, with which they communicate freely. They receive the lymphatics from the organs of the upper part of the abdomen, that is to say, from the liver, stomach, duodenum, and pancreas (head), and, uniting with the superior

FIG. 605.—The lymphatic plexuses of the true and false pelves and their connection with the lymphatic vessels of the lower extremities and of the viscera.

The lymphatic vessels have been injected with India ink.

FIG. 606.—The lymphatic vessels and lymph nodes of the mesentery.

Injection with India ink.

FIG. 607.—The lymphatic vessels and lymph nodes of the thigh, the inguinal region, and the external genitalia.

Injection with India ink.

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mesenteric nodes, they form the *cœliac plexus.* Its efferents unite with those of the mesenteric nodes to form the intestinal trunk, but also pass partly to the lumbar trunk by way of the neighboring lumbar nodes.

4. The *hepatic nodes* (Fig. 390) are small and are situated in the portal fissure and in the hepatoduodenal ligament.

5. The *superior gastric nodes* are small and lie along the lesser curvature of the stomach; the *inferior gastric nodes* are also small and occur along the greater curvature, draining the stomach and duodenum.

6. The *pancreaticosplenic nodes* are situated in the hilus of the spleen; they drain the spleen, the fundus of the stomach, and the cauda and body of the pancreas.

V. THE LYMPHATIC NODES AND PLEXUSES OF THE PELVIS AND LOWER EXTREMITY.

All lymphatics of the pelvis and the lower extremity communicate on either side with the lumbar trunk and through this reach the thoracic duct. The *lumbar trunk* starts in a plexus of nodes, which extends along the common iliac artery and is called the *lumbar plexus;* from here it passes upward along the lower portion of the aorta as the *aortic plexus* and so reaches the cisterna chyli. The lumbar plexus arises from the union of the *hypogastric plexus*, coming from the true pelvis, and the *external iliac plexus*, which drains the lower extremity.

The Lymphatic Nodes of the True Pelvis.—The nodes of the true pelvis are:

1. The *hypogastric nodes* (Fig. 605), which are about ten medium-sized glands situated on either side on the wall of the true pelvis along the hypogastric vessels, forming the *hypogastric plexus.* They receive some deep lymphatics from the thigh, which accompany the obturator vessels, and others from the gluteal region which reach the pelvis in company with the gluteal vessels and in whose course occasionally small nodes are found. In addition they receive lymphatics accompanying the pudendal vessels from the perineum and the posterior portion of the external genitals, and also the lymphatics of the pelvic viscera (bladder, prostate, seminal vesicles, vagina, uterus). Their efferent vessels pass through the hypogastric plexus to the nodes of the lumbar plexus.

2. The *sacral nodes* are situated partly behind the rectum (small, anorectal nodes) and partly anterior and inferior to the promontory of the sacrum in the mesorectum, these latter forming the continuation of the mesocolic nodes. They collect lymph mainly from the rectum and unite with one another and with the neighboring mesocolic and hypogastric nodes to form the middle sacral plexus. Their efferents pass to the lumbar nodes.

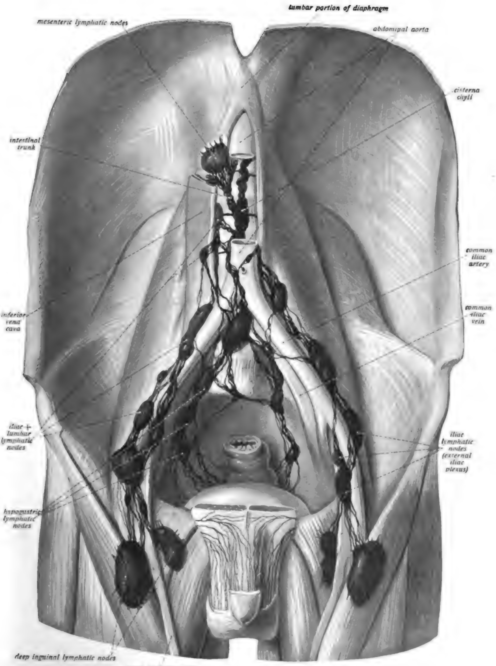
lumbar portion of diaphragm
mesenteric lymphatic nodes
abdominal aorta
cisterna chyli
intestinal trunk
common iliac artery
common iliac vein
inferior vena cava
iliac + lumbar lymphatic nodes
iliac lymphatic nodes (external iliac plexus)
hypogastric lymphatic nodes
deep inguinal lymphatic nodes
great saphenous vein

Fig. 605.

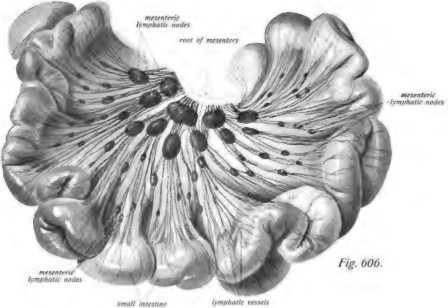

Fig. 606.

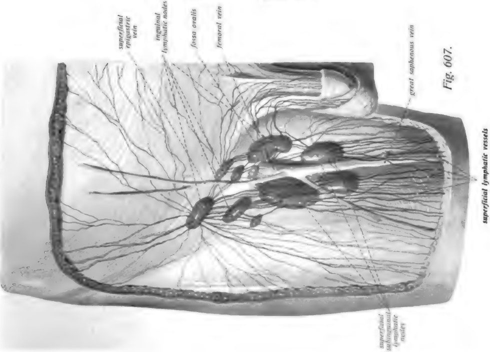

Fig. 607.

The Lymphatic Nodes of the Lower Extremity.—The majority of the lymphatics of the lower extremity, the numerous superficial ones in particular, pass up the medial and anterior surfaces of the thigh in almost parallel courses, having but few anastomoses, to the subinguinal region, where most of them pass through lymph nodes for the first time. Below this region only inconstant nodes occur, such as, somewhat frequently, the *popliteal nodes* in the popliteal space, and more rarely the small *anterior tibial node*, resting upon the upper portion of the anterior tibial artery.

The nodes of the inguinal region receive afferents from the abdominal wall, the external genitals, and the leg. They are divided into the following groups:

1. The *inguinal nodes* (Fig. 607), numbering three to five, lie along the inguinal (Poupart's) ligament, the long axis of the group being parallel to the ligament and generally a little above it. They are situated quite superficially, immediately beneath the skin, and the lateral nodes of the group are smaller than the more median ones.

2. The *superficial subinguinal nodes* (Fig. 607), numbering seven to twelve, are situated superficially, immediately beneath the skin, parallel to the long axis of the thigh in the region of the fossa ovalis and along the termination of the long saphenous vein. An especially large node, in fact, the largest one in the body, lies near the fossa ovalis, frequently immediately in front of it.

3. The *deep subinguinal nodes* (Fig. 605) are the direct continuation of the preceding. They are fewer (three to five in number) and smaller than the superficial nodes and are situated beneath the fascia lata, along the femoral artery and vein, deep in the ileopectineal fossa. One of the nodes of this group occupies the entrance to the femoral canal and is known as the *node of Rosenmüller*.

These three groups of inguinal nodes form an almost unbroken chain, the two groups of subinguinal nodes constituting the *inguinal plexus*. They receive in a somewhat variable manner the superficial and deep lymphatics of the lower extremity, the superficial lymphatics of the gluteal region, the abdominal walls, the penis (clitoris), and the lateral and anterior surfaces of the scrotum (labia major and mons pubis). Their efferents pass to the iliac nodes.

The Lymphatic Nodes and Plexuses of the False Pelvis.—1. The *iliac nodes* (Fig. 605) are fairly large, numbering five to six, and lie along the external iliac vessels. They are united by short afferents and efferents to form the *external iliac plexus* and they receive mainly the efferents of the deep inguinal nodes, and in part also vessels coming directly from the neighboring tissues. Their efferents pass to the lumbar nodes.

2. The *lumbar nodes* (Fig. 605) are about twenty rather large nodes, which are connected to form the *lumbar plexus* and are situated along the common iliac vessels and in the neighborhood of the bifurcation and lower portion of the aorta. They receive the efferents of the iliac, hypogastric, and sacral nodes; the lymphatics from the sigmoid colon; those from the spermatic cord, which convey the lymph from the testes and the epididymis; in the female, the lymphatics from the ovaries, Fallopian tube, and those from the uterus which course along the ovarian vessels; and, finally, those from the kidney and suprarenals as well as from the lumbar region. Their large efferents unite to form the *lumbar trunk* on either side. The superficial and deep subinguinal, iliac, and lumbar nodes form an almost unbroken chain, through which lymph from the lower extremity must pass before emptying into the thoracic duct.

THE NERVOUS SYSTEM.

THE SYSTEM IN GENERAL.

THE study of the nervous system involves its anatomy, and because of its anatomical structure, as well as in regard to its function, it is divisible into two distinctly different portions: The *central nervous system* and the *peripheral nervous system*.

The central nervous system is really the central organ or central station, while the peripheral system is merely a number of conducting tracts representing the conducting wires connected with the station. It contains, of course, paths which are the direct or indirect continuations of conduction paths of the peripheral nerves, but its essential feature is that it contains the real nerve centers. It consists of two not very distinctly separate parts, the brain or *encephalon*, lying in the skull, and the *spinal cord*, occupying the vertebral canal. These two parts constitute the neural canal, and arise in common from the embryonic medullary folds, and throughout life form a long, thick-walled tube, very complicated in structure and general form. The cavity of this tube is narrow throughout the spinal-cord region and is known as the *central canal* (see page 118), while in certain regions of the brain it is quite large and of very variable shape, and forms the so-called *ventricles* and the *cerebral aqueduct*.

The **central nervous system** consists of two macroscopically differently colored substances. One is almost a pure white and is known as the *white substance*, the other, in the fresh condition, has a grayish-red appearance, and is termed *gray substance*. The difference in color depends partly upon the much richer blood-supply received by the gray substance, but mainly upon the distribution of the different nervous tissue-elements (for details see the Sobotta-Huber *Histology*, Lehmann's *Medical Hand-Atlases*, Vol. XXVI.).

The white substance consists mainly of nerve fibers together with a certain amount of neuroglia tissue, while the gray matter consists principally of ganglion cells and abundant neuroglia, with here and there a few nerve fibers. The white encloses the gray substance superficially throughout the entire spinal cord and brain stem, that is to say, the continuation of the cord in the brain.* In the main divisions of the brain, the cerebrum and cerebellum, however, gray substance occurs over the greater part of the surface, covering the white substance, the latter only exceptionally reaching the external surface of the brain in these regions. The gray substance appears partly as a diffuse layer or mass, as in the gray cortex of the cerebral hemispheres and cerebellum and in the columns of the cord, and partly in the form of separate ganglia or nuclei, which, in the region of the cerebral peduncles, for example, form the more or less circumscribed *nuclei of the cerebral nerves*. The white and gray substances are not always clearly separated, but in some regions, as in the spinal cord and the medulla oblongata, they intermingle by means

* In certain regions of the brain-stem the gray substance does reach the surface dorsally, but this is really only an apparent exception to the statement made above, since the gray substance actually forms the boundary walls of the ventricles throughout.

of numerously branched prolongations, forming what is termed a *reticular formation.* Certain portions of the gray, having a rather glassy appearance on account of their containing exceptional amounts of neuroglia, are known as the *gelatinous substance,* and the *ependyma,* which lines the cavities of the central nervous system, is also a special form of neuroglia.* Certain portions of the embryonic medullary tube retain even in the adult their original structure, that is to say, they do not develop into nerve tissue, but present an extremely thin, microscopically delicate roof for the ventricle, known as an *epithelial lamina.* Usually these laminæ are the seat of formation of *chorioidal plexuses* (see below), and they pass over into the nerve tissue by a serrated or irregular edge, termed a *tænia.*

The **peripheral nervous system** consists of two parts: The peripheral *nerves* and small *ganglia* distributed throughout the system. The nerves also are classified as trunks coming directly from the central organ, of whose conduction paths they are either direct or indirect continuations, and the nerves of the *sympathetic system.* The nerves emanating from the central organ itself are divided according to their place of origin into *cerebral* and *spinal nerves.*

The sympathetic system, which for the most part furnishes the nerves of the viscera and blood-vessels, has a separate function and importance; it is connected to the central nervous system only indirectly by *rami communicantes.* In contrast to the cerebrospinal system, the functions controlled by it are involuntary.

In the peripheral nerves, the cerebrospinal as well as the sympathetic, conduction may take place in both directions, centrifugal as well as centripetal. The centrifugal nerves are motor nerves, the centripetal, which include those conveying impressions from the nerve endings in the higher sense organs, sensory. The great majority of the nerve trunks of the human body contain fibers or bundles which conduct in both directions; they are mixed nerves, containing both sensory and motor fibers. Only in the anterior and posterior roots of the spinal nerves and in certain of the cerebral nerves are the two varieties definitely separated.

The nerve terminations also differ according to the mode of conduction (centrifugal or centripetal). Motor nerves which end in muscles convey impulses for a contraction from the central organ to the muscle fiber, while sensory nerve endings receive the impulse and carry it to the central organ.

The peripheral nerves at their origin from the central organ appear as thick strong trunks, which often form *plexuses* by communicating with neighboring nerves, and in their further course to the end organs they branch dichotomously into smaller and smaller branches. Neighboring nerves often anastomose; fibrils of one nerve may pass to another, as in simple anastomoses, where motor fibers join sensory, or mutual anastomoses, where there is an exchange of fibers from both nerves.

The *ganglia* are grayish-red swellings in the course of peripheral fibers, and differ in structure from peripheral nerves by containing ganglion cells. Their size is very variable, many being microscopic, while others attain a size of from 2 to 3 cm., and their form also is inconstant. If they are inserted in the course of an individual nerve trunk they are usually elongated and spindle shaped, while if they are the centers of nerve plexuses they are stellate.

In the cerebrospinal nerves ganglia are found only on the posterior roots of the (cerebral

* For further details see the Sobotta-Huber *Histology,* Lehmann's *Medical Hand-Atlases,* Vol. XXVI .

FIG. 608.—The spinal cord exposed in the spinal canal by the removal of the vertebral arches and of the dura mater.

FIG. 609.—A posterior view of the spinal cord and of the roots of the nerves.
The dura mater has been divided and reflected.

FIG. 610.—An anterior view of the spinal cord.
The anterior roots have been divided close to their origins from the cord.

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and) spinal nerves. The sympathetic system, however, is rich in ganglia, being essentially a network of nerve fibers and ganglia, the latter being partly arranged in a row in the main trunk and partly disposed in the branches, and even in the terminal branches situated in the substance of the viscera.

SPECIAL NEUROLOGY.

THE CENTRAL NERVOUS SYSTEM.

THE SPINAL CORD.

THE *spinal cord* (Figs. 608 to 620) is the lower stem-like division of the nervous system, which is situated in the vertebral canal. It merges at its upper extremity without any sharp line of demarcation into the medulla oblongata, which is regarded as a portion of the brain.

It is a cylindrical cord flattened somewhat here and there, and does not fill the vertebral canal in either breadth or length. Its upper extremity corresponds to the lower border of the foramen magnum, the lower to the level of the first or second lumbar vertebra, there being no portion of the spinal cord in the lowest portion of the vertebral nor in the sacral canal, these portions of the canal containing only nerve roots passing from the cord. The thickness or diameter of the cord varies considerably at different levels, but remains always considerably less than the transverse measurement of the vertebral canal of the corresponding vertebra, so that a cross-section of the spinal cord scarcely occupies half the area of the vertebral foramen. Furthermore, the cord does not lie naked in the vertebral canal, but is enveloped by several connective-tissue membranes.

The diameter of the spinal cord shows a general decrease from above downward, the upper extremity of the cord being by far the thickest, and its lower extremity the thinnest portion. This decrease in diameter is not, however, continuous, but in those regions where the strong nerve trunks destined for the extremities make their exit the cord presents fusiform swellings, and between the two enlargements there is a much narrower portion.

There may be distinguished in the spinal cord three successive divisions (Fig. 610): the upper part, lying in the cervical portion of the vertebral canal, is termed the *cervical portion*, the middle division, longer and thinner, lying in the region of the upper nine thoracic vertebræ, is the *thoracic portion*, and the division situated in the region of the lower thoracic and the first or second lumbar vertebræ is the *lumbar portion*. The upper, more pronounced enlargement, lies at the level of the lower cervical vertebræ and of the first thoracic and is known as the *cervical enlargement.* The lower, less marked enlargement lies in the region of the lower thoracic vertebræ and is known as the *lumbar enlargement*. The lowest portion of the spinal cord, that

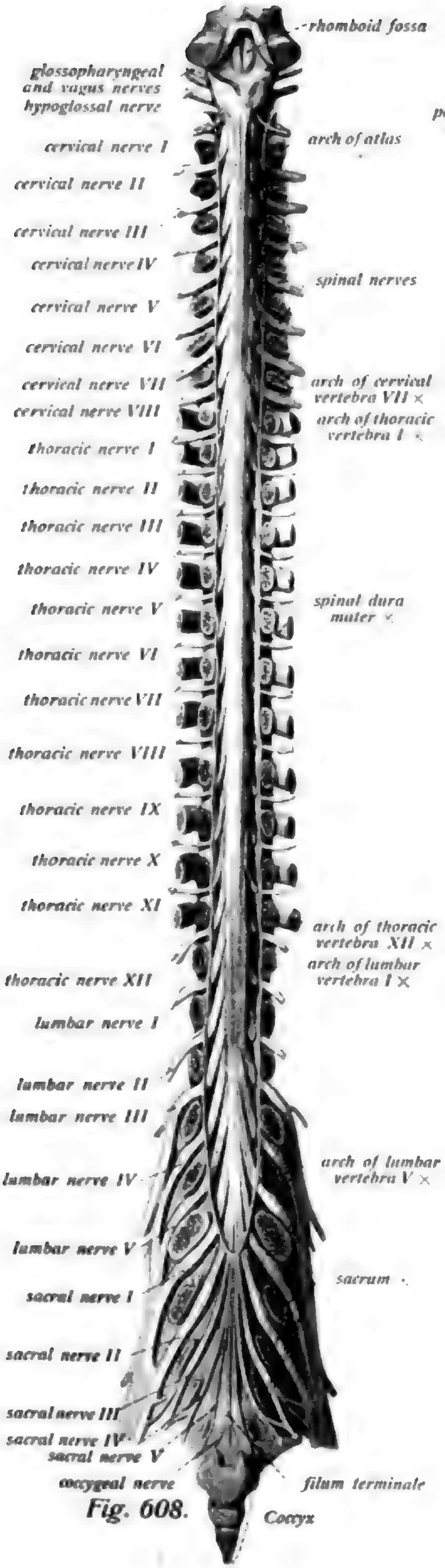

Fig. 608.

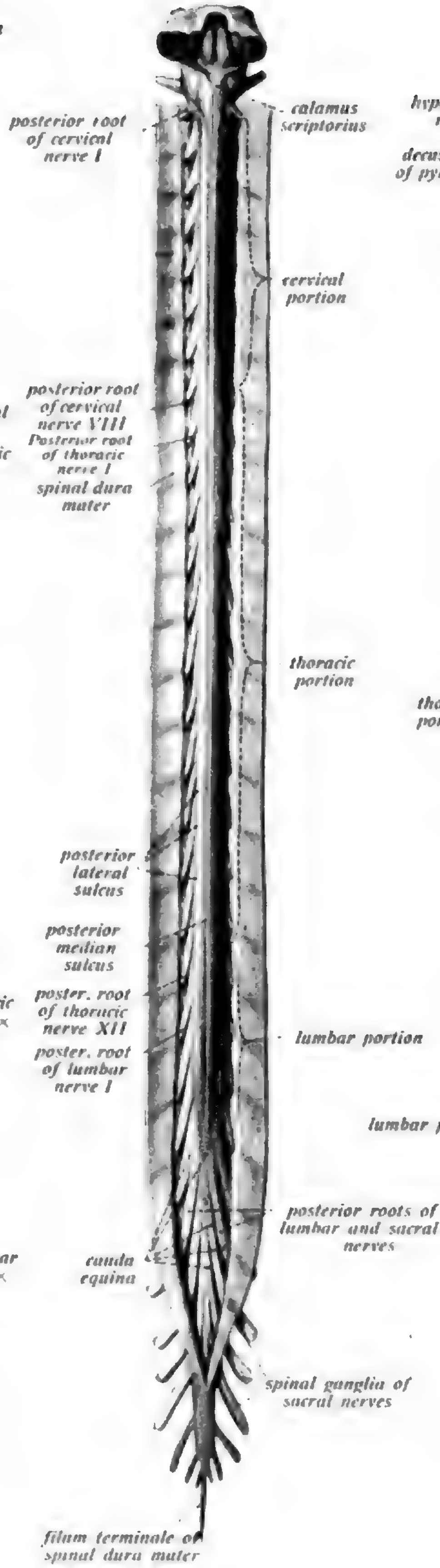

Fig. 609.

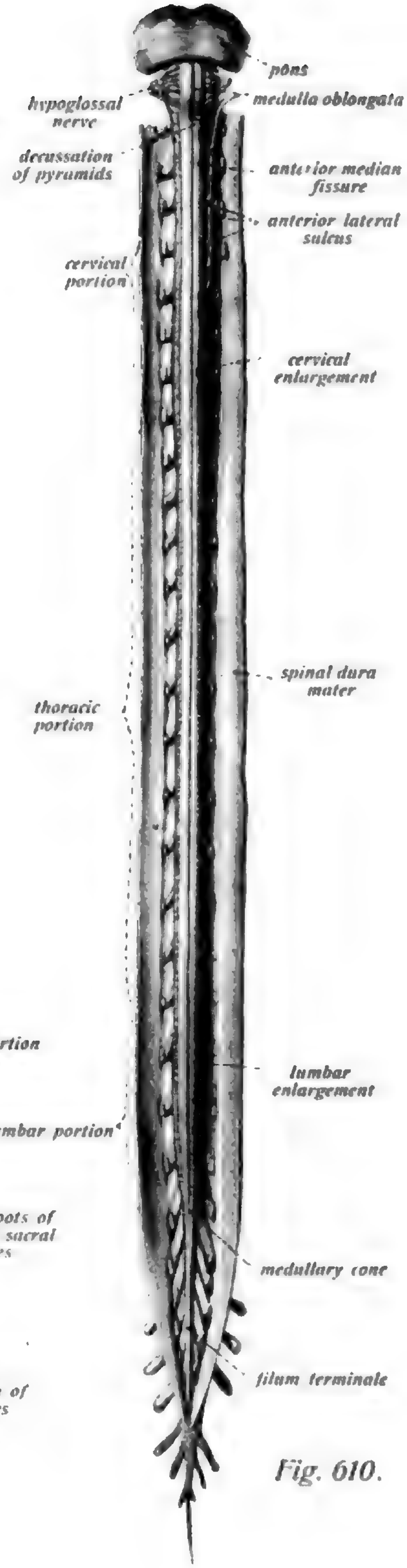

Fig. 610.

lying below the lumbar enlargement at the level of the first lumbar vertebra, tapers off into a short sharp cone, the *conus medullaris*, which is the thinnest portion of the entire cord, and from the apex of this, which in adults corresponds in position to the articulation between the first and second lumbar vertebræ or to the level of the latter, there is continued onward a long, fine, slightly flattened filament about 1 mm. in thickness, which reaches as far as the lower extremity of the neural canal and is termed the *filum terminale*. Although the direct continuation of the cord, this structure contains no nervous tissue or, at most, only remains of it in its upper portion.

The shape of the cord at its different levels is such that in the region of the thorax a cross-section is almost round (Fig. 618) and relatively small. A section through the cervical portion, however, is considerably larger and especially at the cervical enlargement (Fig. 617) has an irregular transversely elliptic shape; the cord being flattened anteroposteriorly in this region. This flattening also occurs in the lumbar portion,* although here it is not quite so marked as in the cervical enlargement, even while being considerably more marked than in the thoracic region, and especially the lower part of this.

Along the median line of the anterior surface of the cord runs a small but deep *anterior median fissure* (Figs. 610 and 614), and opposite this is a shallow furrow, the *posterior median sulcus* from which a connective-tissue partition of pia mater extends into the substance of the cord (Fig. 618), and in conjunction with the anterior median fissure divides the spinal cord into two exactly symmetrical, almost semicylindrical halves. Furthermore, paired lateral sulci may be detected on each side, and correspond to the lines of exit of the nerve roots from the cord, the exit of these being, in fact, the cause of the sulci. An *anterior* and a *posterior lateral sulcus* occurs on either side; the former runs almost parallel to the anterior median fissure and only a short distance from it, lying somewhat closer to it in the lower than in the middle or upper part of its course; the posterior lateral sulcus runs parallel to the posterior median sulcus, but is further away from it than the anterior lateral sulcus is from the median fissure, and, as a rule, it is more pronounced than the anterior sulcus. In the cervical region between the posterior median and posterior lateral sulci there is a *posterior intermediate sulcus*, which vanishes a little below the middle of the cord; it lies rather nearer the posterior median than the posterior lateral sulcus.† The remaining sulci do not become obliterated until they reach the medullary cone, the anterior median fissure being the last to disappear.

By the superficial furrows of the cord, the white substance, which represents a mantle decreasing noticeably and continuously from above downward, is divided into separate bundles, the *spinal funiculi*. On either side three columns can be distinguished: an *anterior funiculus*, between the anterior median fissure and the anterior lateral sulcus; a *lateral funiculus*, between the anterior and posterior lateral sulcus, and a *posterior funiculus*, between the posterior lateral and posterior median sulcus. Of these three funiculi, the lateral is by far the largest, the anterior the smallest. This division of the cord into funiculi is only roughly descriptive; it does not for the most part correspond in any way to the course of the different fiber paths (see below),

* The cross-section of the lumbar enlargement corresponds much more in form to a short ellipse than does the irregular section of the cervical enlargement.

† Occasionally, usually only in the fetus or the newborn child, there is also an *anterior intermediate sulcus*, which indicates the lateral border of the anterior cerebrospinal fasciculus (see p. 116).

FIG. 611.—A posterior view of a portion of the spinal cord with its membranes. Above, the dura mater has been divided and reflected and the arachnoid removed.

FIG. 612.—An anterior view of the spinal cord with the efferent roots of the nerves.

FIG. 613.—A transverse segment of the spinal cord with both spinal ganglia.

FIG. 614.—An anterior view of the lower portion of the spinal cord. The dura mater has been divided longitudinally.

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the division of the posterior funiculus by the intermediate sulcus and the connective-tissue septum starting from it, alone corresponding to the line of separation of the fasciculus gracilis and the fasciculus cuneatus.

The funiculi are again subdivided, according to the fiber paths which traverse them, into fasciculi (Fig. 615), whose boundaries, as a rule, cannot be determined by ordinary anatomical methods.* Thus the **anterior funiculus** has two subdivisions: 1. The narrow *anterior cerebrospinal* (*direct pyramidal fasciculus*), bordering on the anterior median fissure;† it contains a part of the large motor path of the body, the so-called pyramidal tract, and only the direct portion of it, and this is occasionally (generally only in the newborn) separated from the main portion of the anterior fasciculus by the anterior intermediate sulcus.

2. The remaining subdivision is known as the *anterior fasciculus proprius* (*Flechsig*'s *fasciculus*) and contains only short-path fibers from the cells of the spinal cord itself.

The **lateral funiculus** has four subdivisions: 1. The *lateral cerebrospinal* (*crossed pyramidal*) *fasciculus* is a descending centrifugal bundle or motor path which gradually decreases in thickness from above downward and contains the main part of the pyramidal path, the crossed tract (see page 180). It is a strong rounded three-sided fasciculus situated in the dorsal portion of the lateral funiculus and bordering partly on the gray matter of the posterior horn, and throughout the greater portion of its course is covered by the following fasciculus, so that it does not reach the surface of the cord. 2. The *cerebellospinal* (*direct cerebellar*) *fasciculus* is a narrow superficial zone of the dorsal half of the lateral funiculus and contains ascending sensory paths. It is not present in the lumbar region and after its appearance increases in thickness from below upward. Its fibers originate in the cells of the column of Clarke and traverse the spinal cord and medulla oblongata to reach the vermis of the cerebellum. 3. The *superficial anterolateral fasciculus* or *Gower's tract* lies superficially in the ventral half of the lateral fasciculus. The origin of its fibers is unknown, but it forms a sensory, centripetal system of fibers which ascend to the pons and cerebellum. 4. The remaining portion of the lateral fasciculus is occupied by the *lateral fasciculus proprius* (*Flechsig's fasciculus*). It is a very small strip along the lateral border of the gray substance, between the latter and Gower's tract, and contains mainly short-path fibers connecting different regions of the spinal cord, being especially for the fibers bordering upon the gray substance.

* Their delimitation has been determined by the application of special methods to the study of the fiber-tracts of the central nervous system.

† Medial to the anterior cerebrospinal fasciculus there is a narrow tract bordering immediately upon the anterior median fissure. It is known as the *sulcomarginal fasciculus* and descends from the region of the corpora quadrigemina. [And furthermore, a group of somewhat scattered fibers occur on the surface of the anterior funiculus, between the median fissure and the anterior lateral sulcus, and constitute the *anterior marginal* (*Marchi's*) *bundle*, which descends from the cerebellum to the cells of the anterior horn.—ED.]

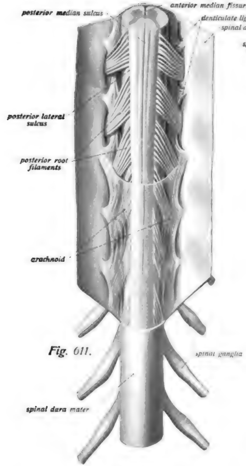


Fig. 611.

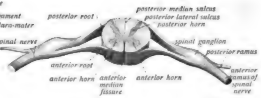


Fig. 613.

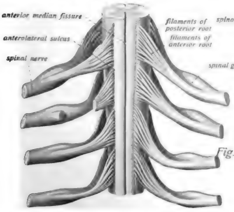


Fig. 612.

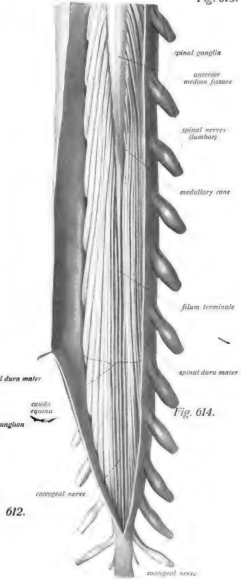


Fig. 614.

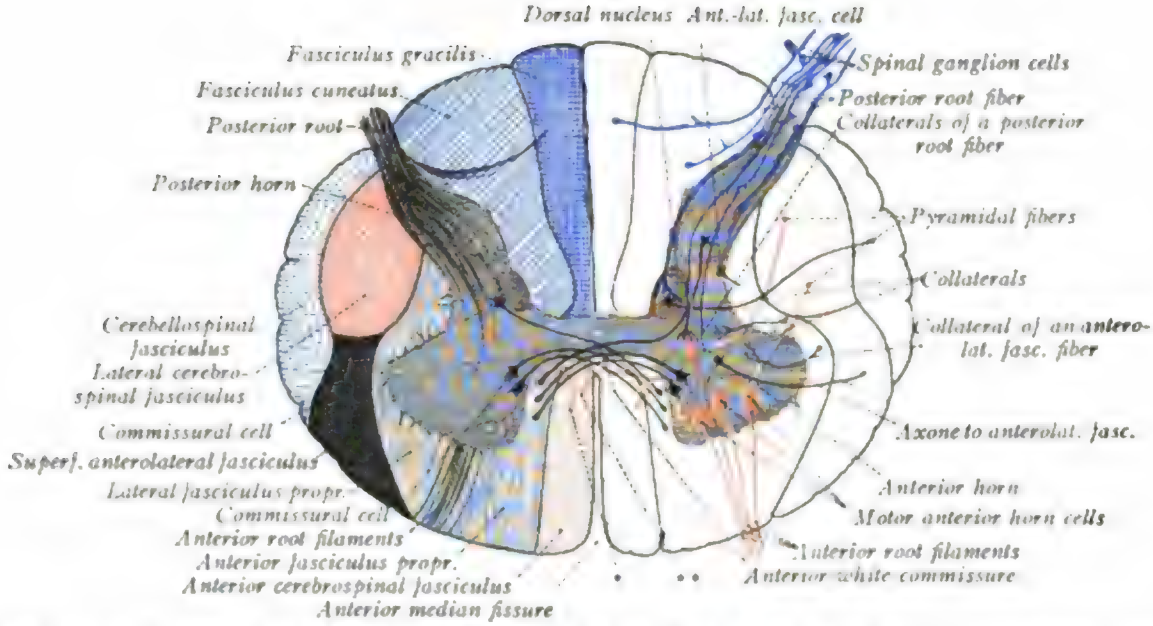


FIG. 615.—Diagram of the columns and of the course of the fibers in the spinal cord. Cerebrospinal fasciculi and motor cells, red (ventral cerebrospinal fasciculus, red streaked, lateral cerebrospinal fasciculus, red cross-hatched; anterior roots, collaterals of the cerebrospinal fasciculi, solid red); spinal ganglion and posterior root fibers, blue; fasciculus gracilis, blue cross-hatched; fasciculus of cuneatus, blue streaked; cerebellospinal fasciculus, blue dotted. * = Uncrossed, * * = crossed fibers of ventral cerebrospinal fasciculus.

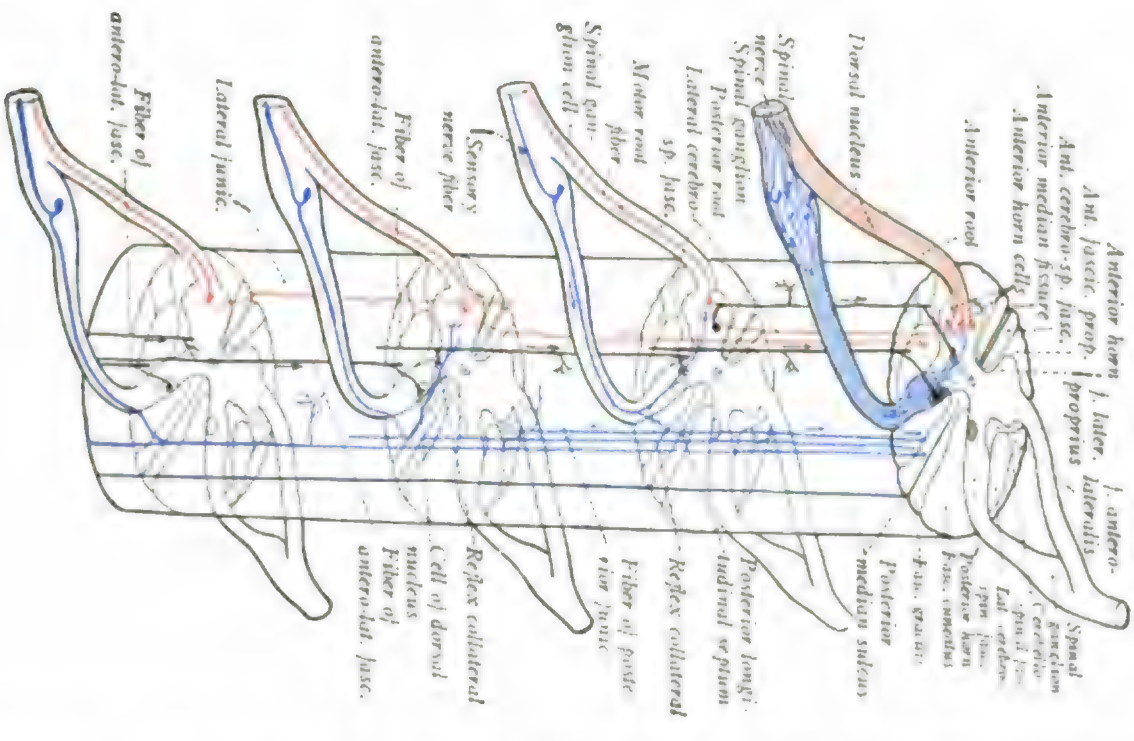


FIG. 616.—Diagram of the course of the fibers in the spinal cord. Motor cells and fibers, red; posterior roots with their collaterals and fibers of the posterior funiculus, blue; column cells, black. The arrows indicate the course of the fibers.

In addition to the short-path fibers the lateral fasciculus proprius contains in its lateral portion some long, slender bundles, such as the ***rubrospinal*** (***Monakow's***) ***tract***, which comes from the red nucleus of the tegmentum, a quadrigemino-thalamus tract, a ***lateral vestibulospinal tract*** from Deiter's nucleus, [and ***Helweg's bundle***, situated superficially near the anterior lateral sulcus and connected above with the olivary nucleus.—Ed.]

The **posterior funiculus** consists of two main fasciculi:

1. The smaller medial portion is the *fasciculus gracilis* (*Goll's column*). It extends as an independent bundle to the lower portion of the thoracic region, and is bounded laterally in its upper part by the intermediate septum of the pia mater, while below it has no visible boundaries. It contains sensory centripetal fibers, which are continuations of posterior root fibers and pass to the nucleus gracilis in the posterior fasciculus of the medulla oblongata (see page 172). 2. The lateral main portion of the posterior bundle is the *fasciculus cuneatus* (***Burdach's column***), which in the upper part of the cord contains short-path fibers and also continuations of posterior root fibers which, as they ascend, are gradually pressed medially toward the region of the fasciculus gracilis.

In the posterior funiculus near the gray commissure there are also nerve fibers from the cells of the posterior horn, and special fibers occur throughout the entire length of the cord in the neighborhood of the posterior septum, forming what are known as the *oval fasciculus* (***median root zone***) and the *ventral area* (*anterior root zone*).

[Furthermore throughout the cervical and upper thoracic regions there occurs in the medial portion of the fasciculus cuneatus a bundle of fibers having a descending direction and forming what is known as the *comma tract* (Schultze's bundle).—Ed.]

The **gray substance of the spinal cord** (Figs. 617 to 620), surrounded on all sides by the white substance, so that it does not reach the surface of the cord directly, is divided into two halves, the *gray columns*, which are united with one another by a narrow bridge, the *gray commissure*. Within this mass, uniting both halves of the gray substance, the remains of the embryonic medullary cavity, the *central canal* of the cord is found in the form of a microscopic axial canal, which is generally obliterated in the adult and presents a well-marked dilatation, the *terminal ventricle*, at the tip of the medullary cone.

The central canal is situated in the gray commissure imbedded in a mass of neuroglia, which is termed the *central gray substance*. This does not occupy the whole width of the gray commissure, but a narrow zone of gray substance lies both in front of and behind it, forming what are known as the *anterior* and *posterior gray commissures*. The former does not directly border upon the anterior median fissure, but is separated from it by a narrow band of white substance, the *anterior white commissure*, consisting mainly of crossing fibers of the anterior pyramidal tracts (see pages 116 and 181).

Each gray column is a mirror picture of the other as is the case with the opposite halves of the entire cord, and, with the uniting commissure, they present a figure like the letter H in cross-sections of the cord. Each gray column is divided into two main parts, a more marked anteriorly directed swelling, the *anterior column* (*anterior horn* of the cross-section), and the less marked, posteriorly directed *posterior column* (*posterior horn*).

These secondary columns are united with one another and also with the ends of the commissure, but are partly separated upon their lateral surface by the fibers of the lateral column,

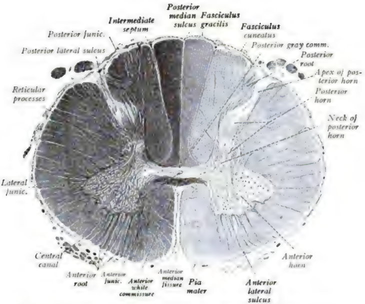


FIG. 617.—A cross-section through the cervical enlargement. (Magnified 8 times.)

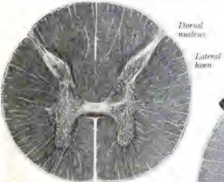


FIG. 618.—A cross-section of the lower thoracic cord. (Magnified 8 times.)

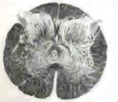


FIG. 620.—A cross-section through the lowermost portion of the lumbar cord. (Magnified 8 times.)

FIG. 619.—A cross-section of the lumbar enlargement. (Magnified 8 times.)

which press medially and occupy a corresponding concavity of the gray column. Here also the line dividing the gray and the white substances, usually clearly separated, is indistinct, the two substances mingling in this region to form the ***reticular formation.*** At certain levels of the cord, especially in the upper thoracic region, the gray ***reticular processes***, which enter the reticular formation, form a lateral projection into the lateral funiculus; this is termed the ***lateral column*** (***horn***) and is regarded as an annex to the anterior column.

The anterior column through the entire length of the cord is thicker than the posterior column. It partly separates the anterior and lateral funiculi and, from the region of its greatest convexity, where it is nearest the surface of the cord, it sends out the ***anterior root filaments***, which leave the cord along the line of separation of the anterior and posterior funiculus, the anterior lateral sulcus. These filaments are processes of the motor cells of the anterior column, the main group of cells of this portion of the gray substance.

The posterior column (Figs. 613 and 617 to 620) arises at the junction of the anterior column and the commissure with a distinct constriction, the ***neck***, upon which follows the ***head***, the thickest part of the posterior column, and which on account of its glassy appearance is known as the ***gelatinous substance of Rolando.**** The column then narrows quickly and decidedly to form the ***apex***, which extends to the bottom of the posterior lateral sulcus and here receives the ***posterior root filaments*** entering the cord. Throughout its entire length the posterior column forms the boundary between the lateral and posterior funiculi. It contains practically only so-called column cells whose axis-cylinders pass to the anterior and lateral fasciculi proprii and partly also to the posterior funiculus. A large group of column cells in the lower thoracic and upper lumbar regions forms the ***dorsal nucleus*** (***column of Clarke***), situated close to the commissure in the neck of the posterior column.

The gray substance of the spinal cord does not decrease in amount from above downward as does the white, but changes its form as well as its size at the different levels of the cord. It is developed most strongly in the region of the two enlargements, which, indeed, are largely caused by the increased amount of the gray substance. The gray substance is least developed in the interval between the two enlargements, that is to say, in the thoracic cord, and the lumbar enlargement is characterized by especially thick posterior columns, so that in the lower portion of the cord the gray substance presents in cross-sections a more plump appearance.

On account of the external form of the spinal cord as described above, the gradual decrease of the white substance toward the lower levels and the arrangement of the gray at different levels in the cord, it is not difficult to recognize the level at which a given section of the cord is taken. In the cervical portion, especially at the enlargement, the cross-section is transversely oval, the white substance is abundant, the anterior columns are broad and the posterior narrow, the gray commissure is wide, the lateral columns and the columns of Clarke are lacking, and the posterior fasciculus is plainly divided into the columns of Goll and Burdach by the intermediate septum. In the thoracic region the cross-section is almost circular, the area of gray substance is small, the anterior horns are especially narrow, the gray commissure is decidedly narrower than in the cervical region, the lateral horns are well developed in the upper thoracic, and the columns of Clarke in the lower thoracic portion, and since the area of gray substance is small, the amount of white substance is considerably larger than that of the gray.

The lumbar cross-section is again transversely oval, not so distinctly so, however, as that of the cervical enlargement. In the upper portion of the lumbar cord, Clarke's columns are still present and the mass of gray is about equal

* The gelatinous substance of Rolando is by no means entirely composed of neuroglia, but also contains in the cervical region small ganglion cells, as, for example, the cells of the nucleus of the spinal tract of the trigeminal nerve.

to that of the white. In the actual lumbar enlargement the relative amount of gray substance increases, the posterior horns becoming characterized by their great width, and the increase continuing toward the lower end of the enlargement, the gray mass becomes larger than the white, an appearance which increases until at the base of the medullary cone the gray columns are covered only by a very narrow zone of white substance.

THE ROOTS OF THE SPINAL NERVES.

All along the spinal cord and symmetrically from both halves of it, pairs of nerves arise, called spinal nerves (Figs. 608 to 614). There are thirty-one pairs of them. The nerves of each pair have their origin from the left or right side of the cord at the same level, and each nerve arises by two separate roots which emerge at the anterior and posterior lateral sulci, and are accordingly termed the ***anterior*** and ***posterior roots.***

The anterior is the motor root and represents the centrifugal path entering the spinal nerves to pass to the muscles, the posterior is the sensory root, the centripetal path entering the cord and conveying impulses from the sensory end-organs. The separate nerve bundles which leave the cord in the anterior lateral sulcus or enter it at the posterior lateral sulcus are known as ***root filaments,*** and in the anterior root they appear as numerous thin threads, while in the posterior root they are thicker, but less numerous. The whole number of nerve fibers is much greater (almost three times as great) in the posterior root than in the anterior, and the posterior roots are, therefore (those of the first cervical nerves excepted), always the stronger.

Since the root fibers diverge toward the spinal cord and converge toward the spinal ganglia, each of the two (posterior and anterior) lateral sulci of the cord presents an almost continuous row of nerve fibers, which is continued uninterruptedly to the lower end of the cord, the last root filaments emerging from the medullary cone. The lines of emergence of the lower nerve roots, on either side, are very close together, being separated only by a narrow space; those of the upper thoracic nerves are furthest from the median line, even further than in the cervical nerves.

The left and right roots of any pair of nerves are generally of equal size, but not infrequently variations occur, so that one root is considerably larger than that of the other side; this inequality, however, being equalized by the next root above or below being correspondingly larger or smaller, as the case may be. For an equalization of the number of nerve fibers anastomoses, known as ***ansæ,*** occur between separate nerve roots, especially in the case of the posterior cervical roots. Occasionally small ganglia occur in the course of the posterior root fibers, forming the so-called ***aberrant ganglia.***

The size of the individual roots varies and generally corresponds with the spinal enlargements in such a way that the largest nerve root arises from the region of greatest enlargement, so that the roots of the sixth cervical and second sacral nerves are the largest, those of the first cervical and coccygeal the smallest, and those of the thoracic nerves distinctly weaker than those of the cervical and lumbar nerves. The anterior and posterior roots of either side unite to form the ***spinal nerves*** (Figs. 608, 612, and 613). According to their places of emergence from the vertebral canal these may be divided into eight pairs of ***cervical,*** twelve pairs of ***thoracic,*** five pairs of ***lumbar,*** five pairs of ***sacral,*** and one pair of ***coccygeal nerves,*** and since each nerve arises from a union of an anterior motor and a posterior sensory root, it is a mixed nerve.

Shortly before uniting to form the mixed nerve the root fibers converge in a fan-like manner to a rounded nerve bundle, the real root, and in addition the posterior sensory root, just before

uniting with the anterior, forms an elongated spindle-shaped ganglion, the ***spinal ganglion**** (Figs. 612 and 613) whose size is relative to that of the root on which it occurs. Although the anterior root rests directly on the anterior surface of the ganglion, its fibers take no part in its formation, and the color of the spinal ganglia, being gray, contrasts with the pure white color of the nerves. The spinal ganglia of the cervical, thoracic, and lumbar nerves are situated in the intervertebral foramina, those of the sacral nerves in the sacral canal, but external to the dura mater (see below), and that of the coccygeal nerve, the smallest of all, generally within the dural sac.

Since the nerve roots arise at rather small intervals from the relatively short spinal cord (it reaches only to the first or second lumbar vertebra) and since there is a continuous decrease in the intervals from above downward, so that at the lumbar enlargement the root filaments form an unbroken row, while the interval between the intervertebral foramina, through which the spinal nerves leave the vertebral canal, become gradually larger because of the increasing height of the vertebra, the length of the individual spinal nerve roots must increase considerably toward the lower part of the series. Only the upper cervical nerves have roots passing horizontally or nearly so;† even the middle cervical nerves must take an oblique course to arrive at their respective intervertebral foramina. The lower the origin of a nerve the more oblique and the longer must its roots be, and since the last sacral nerves emerge from the last sacral foramina, but arise from the cord at the level of the first lumbar or twelfth thoracic vertebra, they must traverse a distance of 10 cm., the coccygeal nerve about 14 cm., or more, within the vertebral canal (and the sacral canal). Consequently, the roots of the lumbar and sacral nerves, which arise at the lumbar enlargement, pass almost vertically downward and surround, like a horse's tail, the filum terminale, close to which the coccygeal nerve runs. The mass of nerves thus formed, which fills the lower part of the vertebral and almost the whole length of the sacral canal, surrounded by the dura mater, is the ***cauda equina.***

Each spinal nerve thus formed by the union of the anterior and posterior spinal nerve roots divides immediately upon its exit from the intervertebral foramen (or in the intervertebral foramina of the sacrum) into two branches, an ***anterior ramus***, which is much stronger than the other, or ***posterior ramus.*** Only in the first, and sometimes in the second cervical nerves, is the posterior ramus thicker than the anterior; in the remaining nerves the reverse holds true, the posterior rami of the lumbar and sacral nerves being especially weak, considering the size of the whole nerve. Both the anterior and posterior rami are mixed nerves. In the sacral region the anterior rami leave the sacral canal through the anterior, the posterior rami through the posterior sacral foramina.

The anterior rami of the spinal nerves have a tendency to unite with neighboring nerve branches to form acute-angled or arched ansæ. These take place especially in the formation of the large plexuses from which the extremities receive their nerves. The anterior branches of the spinal nerves also receive from the sympathetic nervous system ***rami communicantes***, which come from the ganglia of the sympathetic trunk (see page 239).

* The ganglion cells of the spinal ganglia are the actual cells of origin of the posterior root fibers. For further details as to their minuter structure see the Sobotta-Huber *Histology*, Lehmann's *Medical Hand-Atlases*, Vol. XXVI.

† The upper cervical nerves, however, do not pursue a perfectly straight course, but are slightly curved, so that they may not be unduly stretched by movements of the vertebral column.

THE SPINAL MENINGES.

The entire central nervous system, the brain as well as the spinal cord, is enclosed within membranes (Figs. 609 to 611 and 614). According to structure and external appearance only two membranes can be recognized, the dense *dura mater* and a softer internal membrane, but the latter is composed of a more compact layer, the *pia mater*, lying close to the central organ, and a very delicate, lamellar portion, the *arachnoid*, which occupies the space between the pia and the dense dura. The dura mater is a very tough, firm, whitish, shining, fibrous membrane, quite strong in places (especially in the cranial portion) and poorly supplied with blood-vessels, while the softer membrane, especially the arachnoid, is exceedingly thin and lamellar, the cranial portion of the arachnoid in the cranium containing numerous cavities filled with a clear liquid, the cerebrospinal fluid, while the pia mater throughout is very vascular.

Although the structure of the membranes of the brain and the cord is in general essentially the same, a number of differences in detail occur, especially in the case of the dura mater, which is comparatively thicker in the cranium than in the vertebral canal and at the same time takes the place of the periosteum.

The **spinal dura mater** (Figs. 611 and 614) is of medium thickness and forms a long sac loosely surrounding the cord. It begins at the foramen magnum, where it is continuous with the encephalic dura and where it is also closely adherent to the periosteum and the adjacent tectorial membrane. This dural sac extends throughout the entire length of the vertebral canal without filling it, however, and by its pointed extremity reaches to the end of the sacral canal. Here it surrounds only the filum terminale and the pair of coccygeal nerves, forming the filum of the spinal dura mater, and is fastened to the periosteum of the inner surface of the sacral canal and the posterior surface of the coccyx by connective-tissue fibers. While the spinal dural sac is quite a little larger than the thickness of the cord requires, it does not completely fill the vertebral canal, but there always remains between it and the internal periosteum of the vertebral (and sacral) canal an *epidural cavity*, practically filled by the internal vertebral venous plexuses (see page 82) and by a loose, fatty, and very soft connective tissue. Throughout the vertebral canal, therefore, the dural sac is held in position only by tube-like prolongations of it which pass to the various intervertebral foramina, enclosing the roots of each nerve and uniting firmly with the spinal ganglion and spinal nerve, into the neurilemma of which it gradually passes over. The dural sac of the spinal cord shows, therefore, on either side, two rows of lateral openings for the passage of the posterior and anterior roots of the thirty-one pairs of spinal nerves.

The **softer spinal membrane** is divided into the *spinal arachnoid* and a vascular membrane, the *spinal pia mater*.

The *spinal arachnoid* (Fig. 611), like the dura, forms a sac loosely surrounding the spinal cord, but it is much finer and more delicate than the dura, lying close to its inner surface and separated from it only by a potential space, the *subdural cavity*. It is not adherent to the dura except at the intervertebral foramina, where it coalesces with it in the region of the spinal ganglia. Somewhat firmer are its connections with the pia mater, from which it is separated by the *subarachnoid cavity* containing the arachnoid fluid. In addition to numerous delicate connective-tissue fibers that traverse this space, a few firmer connections are found which serve as a suspensory apparatus for the spinal cord in the dural sac. In the first place, rather strong and numerous

connective fibers pass from the pia mater in the region of the posterior median sulcus, forming what is known as the *subarachnoid septum*, and secondly, the pia mater unites with the arachnoid and indirectly with the dura by the *denticulate ligament*, the real suspensory apparatus of the cord. This consists of a paired plate, placed frontally along both sides of the cord, and arises from the pia in the region of the lateral funiculi and is drawn out laterally into a variable number (twenty to twenty-five) of triangular processes, which, covered by the arachnoid, are attached to the inner surface of the dura mater and, in the upper part of the spinal cord, in such a manner that the attachment of each process takes place between the exits of two successive nerve roots.

The *spinal pia mater* (Fig. 611) closely surrounds the surface of the cord and sends a fold into the anterior median fissure as far as the anterior white commissure, so that it covers both surfaces of the fasciculi bordering on the fissure. It passes over the lateral and the posterior median sulci, but sends fine connective-tissue processes of different lengths into the white substance of the cord, the *posterior septum* passing from the posterior median sulcus almost to the posterior commissure, and in the cervical cord, the *posterior intermediate septum*, passing from the posterior intermediate sulcus and separating the columns of Goll and Burdach (see page 118), being two of these processes. The lower end of the pia mater covers the filum terminale, which in its lower portion, where the nerve tissue is absent, is practically formed by the pia.

The pia mater is the vascular membrane of the spinal cord; it contains the larger vessels, as well as their branches, which pass from the membrane directly into the substance of the cord.

THE BLOOD-VESSELS OF THE SPINAL CORD.

The *arteries* of the spinal cord are in the first place the *anterior* and *posterior spinal arteries*, coming from the vertebral. To these come the *spinal rami* of the vertebral, the deep cervical, the intercostal, and the lumbar arteries, which strengthen the spinal arteries descending from the upper part of the cord. The unpaired vessel resulting from the union of the two anterior arteries runs along the anterior median fissure to the base of the medullary cone.

The *veins* do not differ materially from the arteries. The *internal spinal veins* course within the substance of the cord in the region of the central canal, and the *external spinal veins* accompany the arteries along the external surface and are accordingly divisible into the *anterior* and *posterior external spinal veins*. All the veins of the spinal cord enter the internal vertebral venous plexuses.

THE ENCEPHALON.

THE DEVELOPMENT OF THE CENTRAL NERVOUS SYSTEM.

There is no organ in the body for the understanding of whose structure a knowledge of its development is so important as the brain. A short resumé of the development of the central nervous system will therefore be given, especially since the recognized divisions and the nomenclature of the fully developed brain are directly based upon the development of the organ (Figs. 621 and 622).

The first indication of the central nervous system is the medullary plate and medullary canal (see Appendix II.). At an early stage the anterior end of the medullary canal becomes enlarged and represents the foundation of the brain, while the remaining cylindrical portion of the canal becomes the spinal cord. The primitive brain then becomes incompletely separated by two successive constrictions into three enlargements, which are known as the primitive **cerebral vesicles**. The anterior and largest one is the *prosencephalon*, the much more slender middle vesicle, the *mesencephalon*, and the posterior, but slightly enlarged vesicle, the *rhombencephalon*.

Further divisions of the cerebral vesicles now take place. First from either side of the

prosencephalon the eye begins to form as the so-called primary optic vesicle, which in the course of further development (see page 127) remains attached to the brain stem by the stalk-like optic nerve. Furthermore, a division of the anterior and posterior of the three primary vesicles takes place, while the middle one remains undivided, a stage in which the brain consists of fine vesicles* being thus produced. By the division of the prosencephalon there are formed a posterior portion, called the between-brain or *diencephalon,* and an anterior, called the end-brain or *telencephalon* (Fig. 622), and the latter soon gives rise to two (paired) protuberances which in a short time outgrow all other portions of the embryonic brain in size and become the cerebral hemispheres. Thus, the telencephalon consists of a small unpaired and two large paired parts, the cerebral hemispheres. The rhombencephalon divides into a larger anterior portion, the hind-brain or *metencephalon*, and a smaller one, which gradually passes over into the cylindrical spinal cord, and is the after-brain or *myelencephalon* (Fig. 622).

The cerebral canal, thus divided, is not a straight tube, but is much bent upon itself (Fig. 621). In the mesencephalon there is a considerable bend, convex upward, known as the mid-brain flexure, and it forms the most anterior portion of the bent embryonic neural canal. A second bend, posteriorly concave, occurs in the rhombencephalon, and is termed the pons flexure, and finally, in the region of the nape, the canal is again bent upon the cord to form the neck flexure. As a result of these curvatures the unpaired part of the telencephalon almost touches the strong anteriorly directed convexity of the rhombencephalon. Where the mesencephalon passes over into the metencephalon there is a rather marked constriction of the embryonic neural canal, known as *rhombencephalic isthmus.*

Even with these divisions of the embryonic brain, the development of the organ is not nearly complete, but, on the contrary, the embryonic brain as a whole differs greatly from the appearance of the adult brain, even although the various main portions of the brain are indicated by this second division of the neural canal. From the unpaired part of the telencephalon, the optic portion of the hypothalamus, and from the paired part the two cerebral hemispheres arise. The diencephalon gives rise to the mamillary portion of the hypothalamus and the true thalamencephalon; the mesencephalon undergoes the least changes, forming the corpora quadrigemina and the cerebral peduncles; from the rhombencephalic isthmus are formed the brachia conjunctiva and the anterior medullary velum; from the metencephalon, the pons and cerebellum; and from the myelencephalon, the medulla oblongata. The relations of the different portions of the adult brain to the embryonic vesicles may be seen in the following table:

	Primary Division.	*Secondary Division.*	*Final Condition.*
Cerebrum . . .	Prosencephalon	Telencephalon (End-brain)	Cerebral hemispheres. Optic portion of hypothalamus.
		Diencephalon (Between-brain)	Mamillary portion of hypothalamus. Thalamencephalon.
	Mesencephalon	Mesencephalon (Mid-brain)	Corpora quadrigemina. Cerebral peduncles.
	Rhombencephalon	Isthmus rhombencephali	Brachia conjunctiva.
		Metencephalon (Hind-brain)	Pons. Cerebellum.
		Myelencephalon (After-brain)	Medulla oblongata.

* The term vesicle is not quite appropriate for these structures; they are elongated, rounded out-pouchings of a single continuous cylinder.

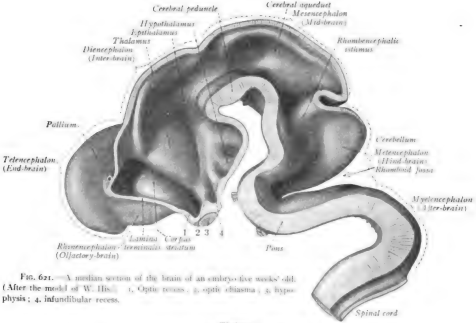


FIG. 621.—A median section of the brain of an embryo five weeks' old. (After the model of W. His.) 1, Optic recess ; 2, optic chiasma ; 3, hypophysis ; 4. infundibular recess.

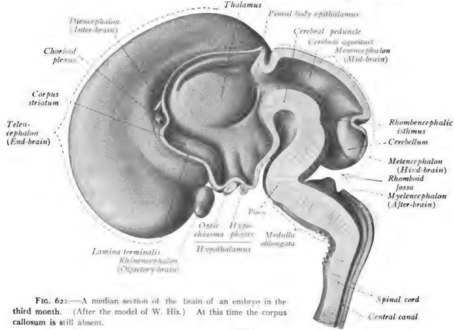


FIG. 622.—A median section of the brain of an embryo in the third month. (After the model of W. His.) At this time the corpus callosum is still absent.

The parts of the brain arising from the embryonic prosencephalon and mesencephalon are collectively spoken of as the cerebrum.

During the development of the embryonic cerebral canal and even before its final division a thickening of both its lateral walls occurs, due to their transformation into nervous tissue, while the base and roof (the so-called floor-plate and roof-plate) remain thin and preserve their epithelial character for a long time, sometimes throughout life. Furthermore, there can be recognized a ventral and a dorsal zone in the lateral walls of the developing canal, and the *limiting sulci* which separate the two zones persist in some regions even in the adult brain. As in the spinal cord, so here, the nerve fibers emerging dorsal to the limiting sulcus are sensory, and those emerging ventrally, motor.

The further development of the embryonic brain to its final condition takes place largely by a very irregular growth of its different parts. In the first place, the cerebral hemispheres grow quickly on all sides and not only cover the whole remaining cerebral canal, but come into contact in the median line above the diencephalon, forming the *longitudinal fissure* of the cerebrum. Certain formations of the brain do not appear until relatively late—*e.g.*, the **cerebellum** and corpus callosum. The former arises by the migration of cells from the upper half of the dorsal zone of the rhombencephalon into the rhomboidal roof-plate, which gives the name to this part of the brain and whose cells do not themselves become nervous tissue. As the migration continues the two thickenings which they form unite in the median line, and, by further growth, gradually cover in the rhomboidal fossa, which, in the embryonic brain, is visible from the surface. The **corpus callosum** develops as a band of transverse fibers, extending between the two cerebral hemispheres by way of the upper part of the anterior wall (lamina terminalis) of the prosencephalon, and gradually enlarges as the hemispheres increase in size. An apparent partial coalescence occurs between the diencephalon and the cerebral hemispheres which overlap it, the medial wall of each hemisphere being fused with the lateral wall of the diencephalon or thalamus, while a *transverse cerebral fissure* separates the floor of the telencephalon and the roof of the diencephalon throughout life (see page 134). In the roof-plate of the diencephalon, just as in that of the rhombencephalon, no nerve tissue is developed (see page 156). The mesencephalon undergoes the fewest changes, its walls thickening quite uniformly on all sides. The lumen of the medullary canal, originally simple, becomes differentiated into portions corresponding to the individual vesicles and forms the ventricles of the brain together with the cerebral aqueduct, and on the development of the cerebral hemispheres is prolonged into them to form the lateral ventricles.

In those regions in which the roof- or floor-plates of the embryonic cerebral canal do not become converted into nerve tissue, but remain in an epithelial condition, as in the rhombencephalon, the diencephalon and the floor of each cerebral hemisphere, vascular proliferations of the pia mater force the epithelial covering into the ventricle and form the *chorioidal plexuses*, which are of great importance for regulating the pressure of the cerebrospinal fluid found in the ventricles.

These appear comparatively early and invaginate the *chorioidal lamina*, as the epithelial wall of the ventricle is termed, into the cavity of the ventricle, so that all portions of the vascular plexuses are covered by epithelium, which proliferates even after the invagination is completed,

but never gives rise to nerve tissue. The pia mater which covers an epithelial lamina which forms a portion of the wall of a ventricle is termed the *tela chorioidea.*

Not until late in embryonic life do fissures and convolutions appear on the surface of the telencephalon. The first invaginations of the surface of the hemispheres, called primary fissures (see page 136), are found in the sixth month of fetal life. However, at the time of birth all convolutions are present, so that the brain of the newborn does not differ materially * from that of the adult.

Much simpler is the development of the **spinal cord.** Here, also, the lateral walls of the canal thicken and become converted into nervous tissue, while the roof-plate and floor-plate remain thin. The lumen of the canal, which later becomes the central canal, is, therefore, for a time a sagittal slit. From the roof- and floor-plates, by their folding in and the formation of the anterior fissure and the posterior sulcus, the two halves of the gray commissure are formed. Originally the spinal cord extends throughout the entire length of the vertebral canal, but later its growth is slower than that of the canal, so that it seems to recede. A result of this unequal growth of the vertebral canal and spinal cord is the formation of the cauda equina, which owes its existence partly to the formation of the filum terminale as a result of the growth in length of the vertebral canal, and partly to the oblique course which the lower nerve roots are obliged to take.

THE BRAIN IN GENERAL. DIVISIONS OF THE BRAIN.

As regards the external form of the whole brain, two main surfaces may be recognized: One, the larger, is convex throughout and in its form corresponds almost exactly to the concavity of the inner surface of the roof of the skull; it is known as the ***convex surface of the cerebrum***, for the ***cerebrum*** only takes part in its formation. The second surface corresponds in general to the inner surface of the base of the skull, and is, therefore, largely convex, but also sinuous and of very variable form; it is termed the base of the encephalon.

The external form of the brain corresponds in general to the interior of the skull, which for the most part (if not completely) is occupied by the brain. According to the different forms of the cranial cavity, so differently shaped brains, some longer, some shorter, occur, and just as the length, breadth, and height vary within rather wide limits, so also does the weight of the brain. The male brain is heavier than that of the female, the former averaging 1375 grams, the latter 1250 grams; very rarely a weight of 2000 grams is reached or even surpassed, and still more rarely does the weight fall below 1000 grams.† The length of brain averages 110 to 170 mm., and the greatest width is 140 mm.

The consistency of the brain is soft, though variable in different parts; it is not, however, appreciably softer than the spinal cord. According to its development (see page 124) it is divisible into two main parts: the ***prosencephalon*** and the ***rhombencephalon***, but from its external form it is divisible into three parts: the ***cerebrum***, in which is generally included in addition to the prosencephalon, the mesencephalon, the ***cerebellum***, and the *brain stem.* By the latter is understood the

* The only important difference is, that many paths of the central nervous system are not yet medullated in the newborn child. The formation of the medullary sheaths is in many cases postembryonic.

† The brain in the lower races of mankind (negro, Australian) show a lower average weight than that of Europeans.

medulla oblongata and the pons, that is to say, the rhombencephalon without the cerebellum.* These three main divisions are distinctly characterized by their external peculiarities. The brain stem appears to be a continuation of the spinal cord, not only on account of its continuity with it, but on account of its general external appearance, and especially because its surface (and that of the mesencephalon also) is formed by white matter in contrast to that of the cerebellum and cerebrum.

The cerebrum and cerebellum are entirely independent of one another, and are separated by a deep transverse cleft into which a portion of the dura, the tentorium cerebelli, projects, a connection between the two occurring only in that the cerebellum is connected with the brain stem and this by the mesencephalon is connected with the cerebrum. The two parts present several common characteristics. Both have their surfaces formed of gray substance, the *cortical substance;* both have sulci which penetrate the gray substance and produce convolutions, *gyri,* lying between neighboring sulci; both have symmetrical halves called *hemispheres.* However, decided microscopical differences exist between the gray substance of the cerebrum and that of the cerebellum, the sulci of the cerebellum are much narrower, the convolutions which these form are more slender, and the sulci run almost parallel with one another, while in the cerebrum they are much more irregular; furthermore, the two cerebral hemispheres are almost completely separated by a deep cleft, while the cerebellar hemispheres are united by a median portion, the *vermis of the cerebellum.*

In the brain a system of cavities filled with a clear fluid, the cerebrospinal fluid, occurs,† and these are products of the differentiation of the embryonic medullary cavity (see page 124) and in the different sections of the brain receive different names. Each cerebral hemisphere has such a complicated space, called the *lateral ventricle,* each of which communicates by a semicircular aperture, the *interventricular foramen,* with the unpaired cavity of the diencephalon, which is known as the *third ventricle.* The ventricular system is narrowest in the region of the mesencephalon, where it forms a narrow canal, the *cerebral aqueduct,* which connects the *third* and *fourth ventricles,* the latter being the cavity of the metencephalon and the neighboring portion of the myelencephalon, while in that part of the latter which immediately succeeds the spinal cord there is a continuation of the central canal.

General Description of the Separate Parts of the Brain.

Before beginning a special description of the various parts of the brain, it will be well to form an idea as to how the organ is constructed from its parts. For this purpose a consideration of three views of the brain may serve: first, that of the convex surface; second, that of the base, and lastly, that of a median section.

THE CONVEX SURFACE OF THE CEREBRUM.

In the examination of the convex surface of the brain (Figs. 590 and 628) one sees the cerebrum or rather the cerebral hemispheres, which are separated from one another by the deeply

* The mid-brain is not infrequently regarded as a portion of the brain stem rather than as belonging to the cerebrum.

† It is the cerebrospinal fluid in the narrower sense of the term that occurs within the ventricular cavities; the same name is also applied to the fluid occurring in the subarachnoid cavity.

FIG. 623.—The base of the entire brain with the points of emergence of the twelve cerebral nerves. Upon the left the entire semilunar ganglion has been retained. The hypophysis has been displaced slightly backward and compressed to expose the infundibulum. The Roman numerals indicate the number of the cerebral nerves.

penetrating *longitudinal fissure*, and whose surfaces form a common convexity, arching in the frontal as well as the sagittal direction. The color of the whole surface is a grayish-red, for only the gray cortical layer is exposed. The hemispheres, on account of their length and breadth, cover all other portions of the cerebrum and cerebellum, and on their convex surfaces a large number of, at first sight, very irregular and often anastomosing sulci will be found, which bound corresponding portions of the surface, known as convolutions or gyri. A number of convolutions together constitute a lobe, and upon the convex surface of the brain portions of a *frontal lobe*, *a parietal lobe*, and an *occipital lobe* are visible.

THE BASE OF THE ENCEPHALON.

The base of the encephalon (Fig. 623) is of a much more complex form than the convex surface of the brain, not only the cerebrum, but to a considerable extent also the cerebellum and the brain stem taking part in its formation, so that portions of all the main divisions (telencephalon, diencephalon, mesencephalon, metencephalon, and myelencephalon, see page 125) may be seen at the base, and in addition all the cranial nerves are exposed on this surface. Beginning its examination at the front and proceeding backward, there are to be seen in its anterior portion the concave surfaces of the two frontal lobes* with their sulci and convolutions, separated from one another by the longitudinal fissure.

On either side parallel to this fissure, runs a flattened band distinguished from the gray cortex of the frontal lobe by its white color, lying in a shallow groove and having anteriorly an oval, somewhat flattened, grayish-yellow enlargement; this is the *olfactory tract* with the *olfactory bulb*. Posteriorly it runs in a shallow, white area, the *olfactory trigone*, which is for the most part covered by the optic nerve. These trigones, together with the olfactory lobes and bulbs, form the *rhinencephalon* or olfactory brain, which is regarded as belonging to the cerebral hemispheres. From the olfactory bulb the fibers of the *olfactory nerve* emerge, this being usually considered the first cranial nerve.

That portion of the cerebrum which lies posterior to the frontal lobe and at the same time projects downward as a strong convexity, its tip, the temporal pole, overlapping the frontal lobe, is the *temporal lobe*. The deep and relatively wide cleft which separates it from the frontal lobe is the Sylvian or *lateral fissure* of the cerebrum; the furrow in which this terminates anteriorly is the Sylvian or *lateral fossa*. The medial borders of the two temporal lobes approach one another so closely that the most medial point is only about 1 cm. from the median line. This point, which is about 3 cm. behind the temporal pole (but is more medially and higher † than it), is called the *uncus*. The space which lies deeply in the base of the brain between the two unci and is about 2 cm. broad, allows the following important structures to be recognized: In the first place, adjoining the posterior end of the longitudinal fissure, there is a deeper mass of white

* The most anterior point of the frontal lobe is called the frontal pole.

† That is to say, regarding it from the base of the brain.

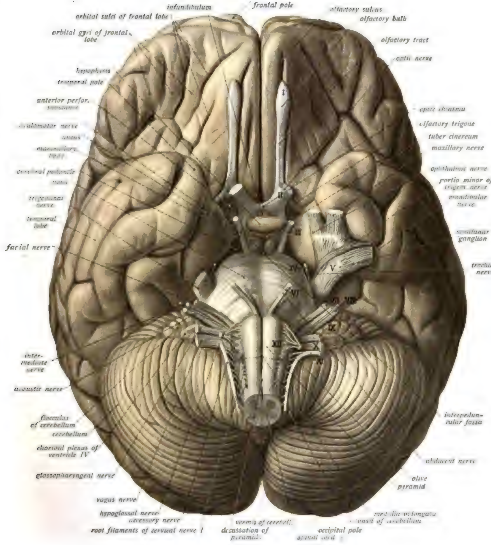

infundibulum
frontal pole
olfactory sulcus
orbital sulci of frontal lobe
olfactory bulb
orbital gyri of frontal lobe
olfactory tract
optic nerve
hypophysis
temporal pole
anterior perfor. substance
optic chiasma
oculomotor nerve
olfactory trigone
uncus
tuber cinereum
mammillary body
maxillary nerve
cerebral peduncle
ophthalmic nerve
pons
portio minor of trigem. nerve
trigeminal nerve
mandibular nerve
temporal lobe
semilunar ganglion
facial nerve
trochlear nerve
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
inter-mediate nerve
acoustic nerve
interpeduncular fossa
flocculus of cerebellum
cerebellum
choroid plexus of ventricle IV
abducent nerve
glossopharyngeal nerve
olive
pyramid
vagus nerve
hypoglossal nerve
medulla oblongata
accessory nerve
tonsil of cerebellum
root filaments of cervical nerve I
vermis of cerebell.
decussation of pyramid.
occipital pole
spinal cord

Fig. 623.

fibers, the *optic chiasma*. It forms a transverse white band from whose extremities two round nerve cords arise and diverge forward and laterally and are known as *optic nerves*, being the second pair of cranial nerves. Passing to the chiasma from behind and laterally are the *optic tracts*, which in an uninjured brain are for the most part covered by the temporal lobes. The optic chiasma is a part of the telencephalon or, more definitely, of the optic portion of the hypothalamus. On either side of the optic chiasma, but somewhat deeper, in the posterior extension of the olfactory trigone there is an area, perforated by blood-vessels, which belongs to the rhinencephalon and is known as the *anterior perforated substance*.

Directly behind the chiasma, suspended by a thin, soft stem, is an irregularly round gray mass, the *hypophysis*, which is also a part of the optic portion of the hypothalamus. It is only loosely connected with the cerebrum and lies in the hypophyseal fossa of the sella turcica. At the place of origin of the hypophysis from the base of the brain there is a slightly convex, grayish mass, the *tuber cinereum*, which is directly continued into the *infundibulum*, as the hollow stalk of the hypophysis is termed.

Behind the tuber cinereum, and still in the deep space between the two unci of the temporal lobes, are two rounded eminences, distinguished by their whitish color; these are the *mammillary bodies;* they lie close to the median line and belong to the mammillary hypothalamus and, therefore, to the diencephalon.

A short distance behind the corpora mammillaria the anterior portion of the pons is seen as a broad expansion, and by the interposition of the broad white brain stem between the temporal lobes and the cerebellar hemispheres the whole configuration of the base of the brain is changed. However, in the narrow space behind the corpora mammillaria, between them and the pons, and in the space between the corpora and the uncus of the temporal lobe, some very important structures, partly covered in, occur. Largely under cover of the uncus, a large white bundle, the *cerebral peduncle* (Fig. 648), emerges on either side from under the pons and diverges forward, the two forming the lateral boundaries of a triangular depression, the *interpeduncular fossa*, which lies immediately behind the corpora mammillaria. Its floor is perforated by numerous blood-vessels, whence it is termed the *posterior perforated substance*. These structures are parts of the mesencephalon. From the interpeduncular fossa on either side of the mesial border of the peduncle the third cranial nerve, the *oculomotor*, has its origin.

The posterior portion of the base of the brain has in the middle line the white brain stem, from which the fourth and fifth to twelfth cerebral nerves arise. Posteriorly it is directly continued into the spinal cord without any sharp lines of division, but its anterior portion is comparatively wide and is known as the *pons* (*Varolii*); the posterior, narrower portion, which is separated from the anterior part by a distinct transverse furrow, is the *medulla oblongata*. These structures belong to the metencephalon and myencephalon (see page 125). The whole brain stem is convex on its ventral surface,* this surface forming part of the base of the brain, but the pons presents a medial shallow indentation, the *basilar sulcus*, caused by the subjacent basilar artery (see page 36); the lateral portions of the pons, however, are convex, and pass laterally and posteriorly as the *brachia of the pons* into the substance of the cerebellum. Distinct, though

* The ventral surface of the crus lies upon the clivus, and therefore looks forward and downward. It forms with the horizontal an angle of about 70 degrees.

shallow furrows pass in an arch-shaped manner over the broad white mass of the pons, which in its anterior portion borders laterally not on the cerebellum, but on the temporal lobes of the cerebrum, which diverge behind the region of the uncus.

From the substance of the pons on either side of the anterior part of the brachium the fifth cerebral nerve, the *trigeminus*, has its origin as a thick, flattened, coarse nerve trunk. Furthermore, from the transverse furrow separating the pons and the medulla the sixth cerebral nerves, the *abducens nerves*, arise, the two being only a few millimeters apart and close to the middle line. The fourth cranial nerve, the *trochlear*, the smallest of all,* is the only cerebral nerve which does not have its origin at the base of the brain. It arises from the dorsal surface of the rhombencephalic isthmus and makes its appearance on the base of the brain in the fissure between the lateral border of the pons and the mesial surface of the temporal lobe on either side.

The pons is succeeded by the club-shaped *medulla oblongata*. Its upper portion adjoining the pons is thickened, while the lower portion, which passes over into the spinal cord, is much thinner. On the whole, the basal surface of the medulla is very similar to that of the cord, especially since the *anterior median fissure* of the latter is continued along the medulla. On either side of the fissure is a distinct fasciculus, the *pyramid*, and at the junction of the medulla and cord the median fissure is interrupted by a crossing of the fibers of the pyramids, which forms the *pyramidal decussation*. The anterior lateral sulcus of the cord also is continued upon the medulla, separating the pyramid from an oval enlargement at the upper part of the medulla, called the *olive*. From the anterior lateral sulcus arise on both sides in the lower portion of the medulla a few anterior root fibers of the first cervical nerves, and in the middle and upper portion the root fibers of the twelfth cerebral or *hypoglossal nerve*. Lateral to the prolongation of the anterior lateral sulcus is the upward continuation of the lateral funiculus of the cord, and in the groove between the brachium of the pons and upper part of the lateral funiculus the seventh and eighth cerebral nerves, the *facial* and *auditory nerves* respectively, arise. At their origin they lie close together, the auditory nerve being thicker and softer than the facial, which is weaker but firmer. In conjunction with both these nerves, another delicate nerve, the *nervus intermedius*, arises, and later on unites with the facial, although at first it is closely associated with the auditory nerve. A little below the origin of the acusticofacial nerves a closely massed group of nerve fibers arises from the lateral funiculus, and are the roots of the ninth and tenth cerebral or *glossopharyngeal* and *vagus* nerves. The eleventh cerebral nerve, the *spinal accessory*, arises not only from the medulla, but partly from the cervical portion of the cord, and runs parallel with this and the medulla, receiving separate root fibers from the lateral portion of the medulla.

On either side of the medulla oblongata and also of the posterior part of the pons, the *cerebellum* or, at least, the two strongly convex cerebellar hemispheres, may be seen toward the posterior portion of the base of the brain, and between the vagoglossopharyngeal and acusticofacial roots the pedunculated *flocculus* is interposed. The vascular plexus of the fourth ventricle also comes into view at the so-called *lateral aperture of the fourth ventricle* (near to the vagoglossopharyngeal root). The cerebellum overlaps the medulla to a considerable extent posteriorly, so that its middle portion, the *vermis*, which anteriorly is covered by the medulla, appears

* If the nervus intermedius be regarded as an independent nerve, so that there are in all thirteen pairs of cranial nerves, then it is the smallest.

for a small distance at the base of the brain; the cerebellum does not, however, occupy all of the remaining surface of the base, but laterally as well as posteriorly the temporal and occipital lobes of the cerebral hemispheres project beyond it. The most posterior point of each cerebral hemisphere is the *occipital pole.*

VIEW OF A MEDIAN SECTION OF THE BRAIN.

The best idea of the structure of the human brain can be obtained by a study of a median longitudinal section (Figs. 624 and 648). Such a section shows, in the first place, the large development of the cerebral hemisphere, in comparison with which all other portions of the brain seem small. Since both hemispheres are united practically only by the corpus callosum, and are throughout the rest of their medial surface separated by the longitudinal fissure, the median section gives a complete view of the mesial surface of the hemisphere, while the diencephalon, mesencephalon, and rhombencephalon, as well as the corpus callosum of the cerebrum and the optic portion of the hypothalamus of the telencephalon, are cut.

The anterior portion of the section is again occupied by the frontal lobes of the cerebral hemispheres, with the *frontal pole* as the most anterior point. Above the corpus callosum is the parietal lobe and behind it the occipital lobe, and in both of these special lobules may be recognized, such as the *paracentral lobule*, the *precuneus*, and *cuneus* (see page 145). The temporal lobe is almost wholly concealed by the brain stem and cerebellum. The most striking feature of the section is the corpus callosum, which appears in cross-section as a rather high, pure white, curved mass, which forms a transverse fibrous connection between the two hemispheres. It presents a *body* which is slightly convex upward and, in addition, a slightly enlarged posterior extremity, the *splenium*, and an anterior portion, the *genu*. From the genu the *rostrum* extends downward and posteriorly and is the thinner portion of the callosum which is continued into a very thin lamina, the *lamina terminalis*, which forms the anterior wall of the third ventricle.

A median section of the brain will, naturally, divide all unpaired cavities, such as the third ventricle, the Sylvian aqueduct, and the fourth ventricle together with its continuation, the central canal of the cord.* On examining a median section of the third ventricle, its peculiar form, produced by its ventral (directed downward) evaginations, which extend into the *hypothalamus*, will be observed. In the upper portion of the cleft-like ventricle the lateral wall is formed by the *thalamus*, the main portion of the diencephalon, and at the lower border of the surface of the ventricular surface of this is a furrow, the *hypothalamic sulcus*, which separates the thalamus from the hypothalamus. The portion of the ventricle belonging to the hypothalamic region possesses two evaginations directed downward; the anterior one, known as the *optic recess*, lies between the lamina terminalis, which forms the anterior boundary of this part of the ventricles, and the optic chiasma, which lies in the floor of the ventricle; the posterior diverticulum is conical in shape and extends from the *tuber cinereum* (see page 131) into the *infundibulum*, and is, therefore, termed the *infundibular recess*. These portions, the lamina terminalis, the optic chiasma, the tuber cinereum, and the hypophysis form the anterior or *optic portion* of the hypothalamus, and belong to the telencephalon.

Close behind the upper border of the lamina terminalis, where this passes over into the

* The cavity of the septum pellucidum (see page 134) is also exposed.

rostrum, is the white circular cross-section of the *anterior commissure*. Furthermore, in front of the lamina terminalis, in the most posterior portion of the adjacent frontal lobe of the cerebrum, lies a portion of the rhinencephalon, rudimentary in man, known as the *parolfactory* (*Broca's*) *area*, bounded in front and behind by the *anterior* and *posterior parolfactory sulci* (Fig. 648).

Behind the tuber cinereum the mammillary hypothalamus with the corpus mammillare will be seen, these parts really belonging to the diencephalon, and behind them the floor of the interpeduncular fossa with the posterior perforated substance and an oblique section of the cerebral peduncle may be seen, these being parts of the mesencephalon.

The surface of the thalamus turned toward the third ventricle is almost plane, being only moderately concave; only a small round area of it, the *intermediate mass*, is cut by a median section, this being an inconstant fusion of opposite thalamic surfaces, which are only separated by a short interval. At the anterior end of the thalamus the *interventricular foramen* may be noticed, leading from the third ventricle into the corresponding (left or right) lateral ventricle. It is situated between the anterior portion of the thalamus and the *column of the fornix*, which also bounds the foramen above. The part of the fornix which projects freely toward the ventricle is known as the *free portion* of the column of the fornix, in contrast to the continuation running in the substance of the ventricular wall (see page 148). Posteriorly the column then curves with an upward convexity into the *body of the fornix*, which lies close to the ventral surface of the corpus callosum. In the region of the genu and the neighboring portion of the body of the corpus callosum, however, the two structures are not in contact, but are separated by two thin gray plates, the *laminæ of the septum pellucidum*, which are situated immediately on either side of the median line, and between the two laminæ there is a cavity, the *cavity of the septum pellucidum*, closed above and anteriorly by the corpus callosum and having no connection whatever with the ventricles, since it is formed only secondarily by the development of the corpus callosum.

The third ventricle is one of those cerebral cavities whose original roof-plate (see page 127) remains in an embryonic condition, so that the roof of the ventricle is formed apparently by the pia mater intruding between the lower surface of the corpus callosum and upper surface of the third ventricle. The space between these two structures is known as the *transverse cerebral fissure* and the double lamina of pia mater lying in it is the *chorioidal tela of the third ventricle*. In its posterior upper portion the third ventricle is bounded by a formation known as the *epithalamus*, which consists of the *pineal body* or epiphysis, which projects backward as a flattened pear-shaped body over the quadrigeminal lamina. Into its stem, the so-called *habenula*, a continuation of the ventricle, the *pineal recess*, extends, and below the recess a white tract, the *posterior commissure*, is seen in section. Below this is the entrance of the *cerebral aqueduct*, the cavity of the mesencephalon.

Of the mesencephalon there can be seen in median section, in addition to the cerebral (Sylvian) aqueduct, first, a longitudinal section of the quadrigeminal lamina, which represents the dorsal portion of the mesencephalon, and second, in the ventral portion, an oblique section of the cerebral peduncle. Below this is the *posterior perforated substance* of the *interpeduncular fossa* with the emerging *oculomotor nerve*.

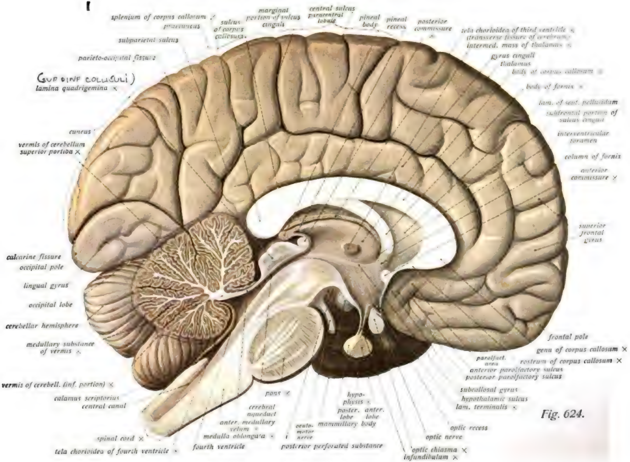

I
splenium of corpus callosum
praecuneus
subparietal sulcus
parieto-occipital fissure
(SUP & INF COLLICULI)
lamina quadrigemina ×
cuneus
vermis of cerebellum
superior portion ×
calcarine fissure
occipital pole
lingual gyrus
occipital lobe
cerebellar hemisphere
medullary substance
of vermis ×
vermis of cerebell. (inf. portion) ×
calamus scriptorius
central canal
spinal cord ×
tela chorioidea of fourth ventricle ×
sulcus
of corpus
callosum
marginal
portion of sulcus
cinguli
central sulcus
paracentral
lobule
pineal
body
pineal
recess
posterior
commissure ×
tela chorioidea of third ventricle ×
(transverse fissure of cerebrum)
intermed. mass of thalamus ×
gyrus cinguli
thalamus
body of corpus callosum ×
body of fornix ×
lam. of sept. pellucidum
subfrontal portion of
sulcus cinguli
interventricular
foramen
column of fornix
anterior
commissure ×
superior
frontal
gyrus
frontal pole
genu of corpus callosum ×
parolfact.
area
rostrum of corpus callosum ×
anterior parolfactory sulcus
posterior parolfactory sulcus
subcallosal gyrus
hypothalamic sulcus
lam. terminalis ×
optic recess
optic nerve
optic chiasma ×
infundibulum ×
pons ×
cerebral
aqueduct
anter. medullary
velum ×
medulla oblongata ×
fourth ventricle
oculo-
motor
nerve
hypo-
physis ×
poster.
lobe
anter.
lobe
mammillary body
posterior perforated substance

Fig. 624.

Another very striking appearance in median section is the section of the *vermis*, as the middle section of the cerebellum is called. The picture presented by this in section is known as the *arbor vitæ*, because the delicate white central mass, the *medullary substance* of the vermis, branches in a dendritic manner, and each of its branches is enclosed by a narrow zone of cortical gray substance.* The vermis then becomes divided into a large number of separate lobes, which bear special names. The medullary substance seen in the median section arises from a thin white plate, coming from the quadrigeminal lamina. This is the *anterior medullary velum* of the cerebellum, which, with the two brachial conjunctiva between which it lies, forms the *rhombencephalic isthmus*. The velum is the actual roof of a portion of the fourth ventricle, the floor of this cavity being formed by the dorsal surface of the *pons* and the upper portion of the *medulla oblongata;* on account of its shape it is called the *rhomboidal fossa*. Posterior and downward the fourth ventricle gradually passes over, at the *calamus scriptorius*, into the central canal of the lower part of the medulla and spinal cord. A longitudinal section of the pons and medulla gives a rather complicated picture as regards the arrangement of the white and gray substances. Although the surface of the brain-stem is of white substance, yet gray nuclei, the *nuclei of the cerebral nerves*, occur in the interior and especially in the surface forming the floor of the fourth ventricle, and it is only in the lower portion of the medulla that the gray substance completely surrounds the central canal and is itself surrounded by the white substance, as in the spinal cord.

A median section also shows that the roof of the fourth ventricle is not completely formed by nerve tissue. In the lower half of the ventricle the cerebellum is separated from the ventricular cavity by an epithelial lamina, which, with the attached portion of pia mater, is known as the *chorioid tela of the fourth ventricle;* it closes the fourth ventricle in a manner similar to the method in which the chorioid tela on the third ventricle closes that cavity.

THE CEREBRUM.

THE PROSENCEPHALON.

THE TELENCEPHALON.

The *telencephalon* or *end-brain* (Figs. 625 to 647, 672, 674, and 675) consists of two parts: an unpaired section, the *optic portion of the hypothalamus*, and a paired one, the *cerebral hemispheres*. The hemispheres include: the mantle or *pallium*, the *rhinencephalon*, the *corpus callosum*, the *fornix*, the *septum pellucidum*, and the large ganglia of the telencephalon, namely, the *corpus striatum*, the *claustrum*, and the *lenticular nucleus*. To the optic portion of the hypothalamus belong: the *lamina terminalis*, the *optic chiasma*, the *tuber cinereum*, and the *hypophysis* with the *infundibulum*.

THE PALLIUM OR MANTLE.

The gray cortex as a whole, together with the subjacent white substance, is called the pallium, and its most noticeable peculiarity is that its surface is marked by fold-like convolutions, the *cerebral gyri*, bounded by usually very irregular deep furrows, the *cerebral sulci;* some of the

* The gray cortex of the cerebellum even macroscopically (especially in brains which have been hardened with chromic salts) is divisible into an inner darker zone, the stratum granulosum, and an outer lighter one, the stratum cinereum.

deeper sulci are known as *fissures*. Certain convolutions which lie deeply seated and cannot be seen on the surface are the *deep gyri*, and the smaller ones connecting the main gyri or two different lobes are termed *transition gyri*.

The entire hemisphere is divided into four lobes, the *frontal*, *parietal*, *occipital*, and *temporal*, to which another portion, the *insula* is added.

Each hemisphere is a mirror image of the other, and as regards the details of development or location of the gyri and sulci, the two usually show but inconsiderable and always unimportant differences. In its external form each cerebral hemisphere is elongated and rounded, the posterior and anterior ends being tapered, but rounded off. The *medial surface* (Fig. 632) bounding the longitudinal fissure is flattened and almost plane, and extends down to the superior surface of the corpus callosum, and above it passes over by a rounded border, the so-called angle of the pallium, into the upper lateral *convex surface* of the hemisphere. The *inferior surface* (Fig. 630) is concave in the region of the frontal lobe and convex in the anterior part of the temporal lobe, this lobe being, however, decidedly concave in its posterior part as is also the neighboring part of the occipital lobe. The latter concavity is due to the cerebellum, which with its convex surface underlies the cerebrum in this situation. The inferior surface also presents a groove-like depression corresponding to the lesser wing of the sphenoid, between the frontal and temporal lobes; this is the Sylvian or *lateral cerebral fossa* which is continued upon the convex surface of the brain. In general, the shape of the anterior portion of the inferior surface is determined by the form of the inner surface of the base of the cranium, upon which it lies and upon the bones of which it leaves digital impressions.*

On each cerebral hemisphere are three points called poles, where the pallium has its greatest extension in a given direction. The most anterior point of the frontal lobe is the *frontal pole*, the most posterior point of the occipital lobe is the *occipital pole*, and the most external point of the temporal lobe, projecting forward and downward, is the *temporal pole*.

Those fissures of the brain which appear first during embryonic development (see page 128) are known as primary fissures and are three in number: 1. The largest of all the cerebral fissures, the Sylvian or *lateral fissure* (Figs. 625 and 626), arises from the lateral cerebral fossa, passes upward and backward on the convex surface separating the temporal from the frontal and parietal lobes. 2. The second primary fissure is that of Rolando or the *central sulcus* (Figs. 626 and 627), which extends at almost a right angle from the pallial angle down almost to the lateral cerebral fissure; it is regarded as the fissure separating the frontal and parietal lobes. 3. The third is mainly developed on the medial surface of the hemisphere and is known as *parieto-occipital fissure* (Fig. 632). It separates the occipital and parietal lobes, but in the human brain it extends upon the convex surface but a short distance beyond the pallial angle.

The other fissures are much narrower and in addition are irregular as regards their development and arrangement. The convolutions also differ in development, not only varying individually in number or size (width), but also presenting certain definite modifications in every brain. Thus, the anterior end of the frontal lobe and the temporal lobe has narrow, generally greatly curved gyri, separated only by shallow fissures, while in the parietal and temporal lobes and in

* The *petrosal impression* is a shallow, easily obliterated impression on the inferior surface of the hemisphere due to the superior angle of the pyramid. It indicates approximately the line of division between occipital and temporal lobes.

the posterior portion of the frontal lobe the sulci are much deeper and the gyri usually considerably broader. It has already been mentioned above that the gyri of the two hemispheres do not correspond in every detail.

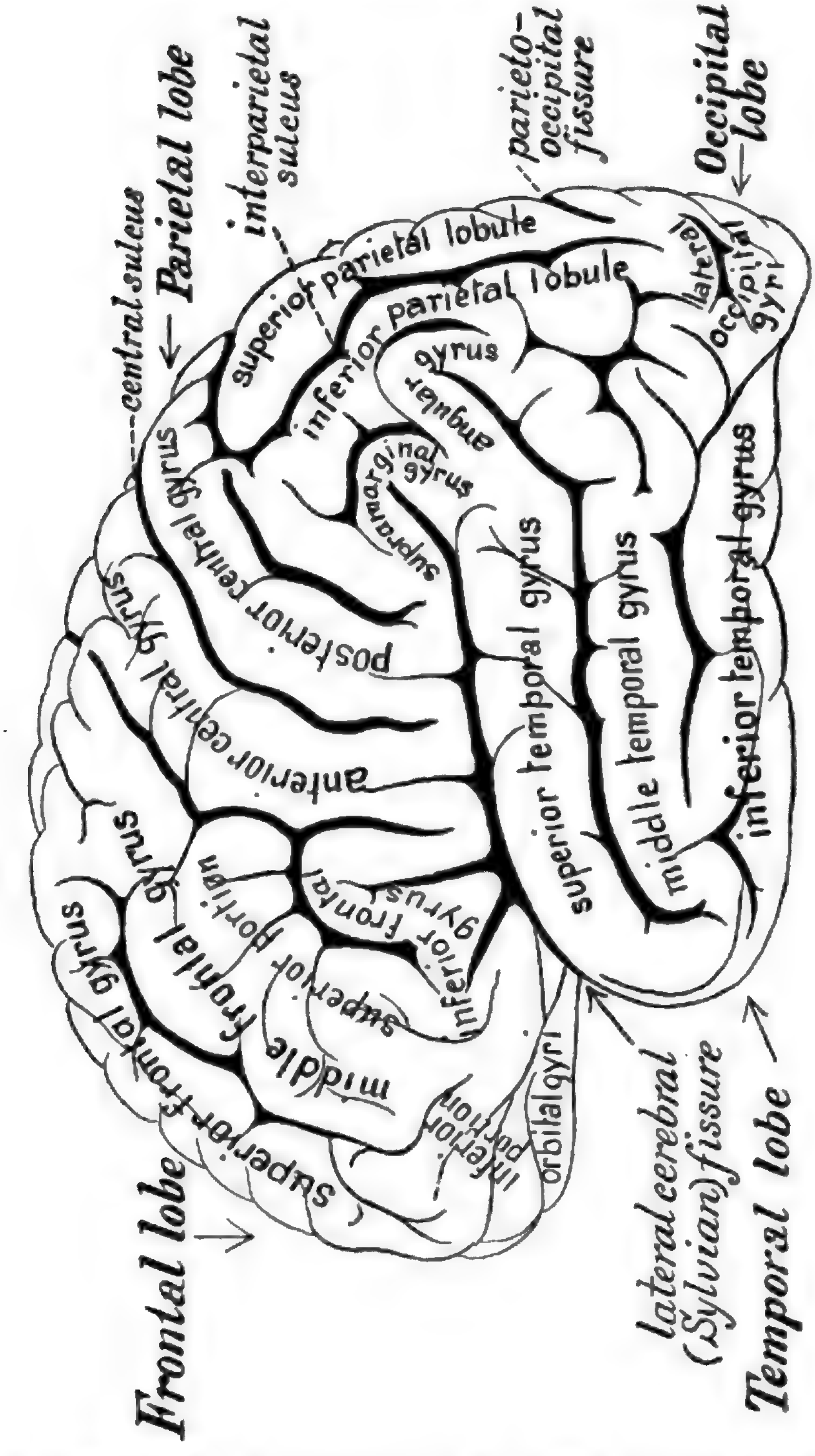
The apparent irregularity in the arrangement of the gyri of the pallium may be simplified by neglecting all smaller and accidental ones which are numerous and vary greatly individually, and the remaining more constant ones may be grouped according to their distribution in the various lobes in the following manner:

1. **The Frontal Lobe.**—The frontal lobe (Figs. 625 to 632) is the anterior part of the hemisphere and its anterior portion forms the *frontal pole*. Its inferior surface rests upon the orbital surface of the orbital portion of the frontal bone and is slightly concave; its mesial surface is flat, as is also the whole mesial surface of the hemisphere, and its dorsolateral surface is convex. Its anterior part is free on all sides and the posterior part borders upon the lateral cerebral fossa and the anterior portion of the lateral cerebral fissure. Posteriorly, the frontal lobe extends to the central fissure which is regarded as the separation between the frontal and parietal lobes.*

As regards its sulci and gyri, the frontal lobe shows a different condition on its inferior surface on the one hand, and on its mesial and dorsolateral surfaces on the other. Its large main gyri are on the latter two surfaces and consist of three sagittal gyri, termed the ***superior frontal***, ***middle frontal***, and ***inferior frontal*** gyri. These are separated by two corresponding fissures, the ***superior frontal*** and the ***inferior frontal sulci*** which start at the anterior border of the anterior central, or precentral sulcus, so that only from this line forward are the three frontal gyri recognizable.

The ***superior frontal gyrus*** (Figs. 625 to 632) lies partly on the convex but also largely on the mesial surface of the hemisphere, and as a narrow band the ***gyrus rectus*** (Figs. 630 and 631), which is separated from the orbital gyri by the olfactory sulcus, it extends to the inferior concave surface of the lobe. The ***middle frontal gyrus*** (Figs. 625 to 628) is on the convex surface between the superior and median frontal sulci, and in it there may be distinguished an upper ***superior portion***, and a lower ***inferior portion*** directed toward the convex surface of the lobe. The ***inferior frontal gyrus*** (Figs. 625 and 626) extends from the inferior frontal sulcus to the lateral cerebral (Sylvian) fissure and the lateral cerebral fossa and to the lateral free surface of the lobe, where it passes over, without any sharp line of demarcation, into the orbital gyri. It lies, therefore, on the lateral convex surface of the lobe and presents three distinct portions separated as follows: The lateral cerebral (Sylvian) fissure consists of an almost horizontal ***posterior ramus***, and an upwardly directed ***anterior ramus***, and this latter is split in a fork-like manner into an anterior almost horizontal limb, the ***anterior horizontal ramus***, and a posterior, almost vertical branch,

* It would be better to place the posterior boundary of the frontal lobe at the precentral sulcus for the following reasons: 1. The three frontal gyri extend only to this sulcus. 2. The anterior central gyrus, lying between the precentral and central sulcus, is closely connected with the posterior central gyrus, lying behind the central sulcus, not only in function, but topographically (in the region of the operculum and paracentral lobule), so that a division between the two lobes along the line of the central sulcus is impossible. 3. If the central sulcus be taken as the posterior boundary of the frontal lobe the latter is not only very long (and the parietal lobe correspondingly short), but it extends far beyond the frontal region into the parietal region. Furthermore, the paracentral lobule then belongs partly to the frontal, and partly the parietal lobe, without any apparent line of separation, because the central fissure does not extend into it.



FIGS. 625 and 626.—The fissures and convolutions of the cerebral cortex as seen from the left side. The cerebellum and brain-stem have been removed.

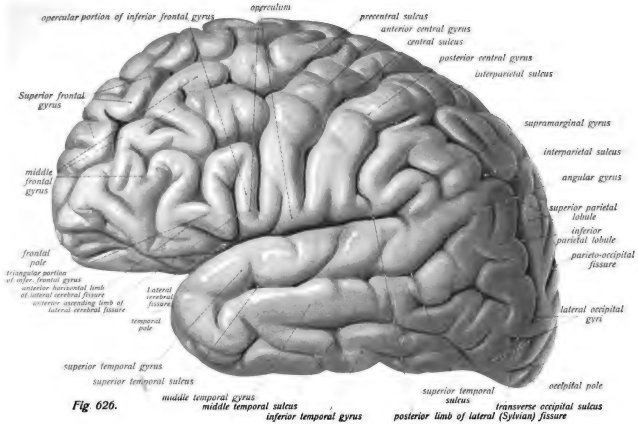

opercular portion of inferior frontal gyrus
operculum
precentral sulcus
anterior central gyrus
central sulcus
posterior central gyrus
interparietal sulcus
Superior frontal gyrus
supramarginal gyrus
interparietal sulcus
middle frontal gyrus
angular gyrus
superior parietal lobule
inferior parietal lobule
frontal pole
parieto-occipital fissure
triangular portion of infer. frontal gyrus
anterior horizontal limb of lateral cerebral fissure
anterior ascending limb of lateral cerebral fissure
Lateral cerebral fissure
lateral occipital gyri
temporal pole
superior temporal gyrus
superior temporal sulcus
occipital pole
middle temporal gyrus
superior temporal sulcus
middle temporal sulcus
transverse occipital sulcus
inferior temporal gyrus
posterior limb of lateral (Sylvian) fissure

Fig. 626.

the ***anterior ascending ramus***. Both these branches advance into the substance of the inferior frontal gyrus, and that part of it lying in the fork of the anterior ramus of the lateral fissure is the ***triangular portion***, that lying in front of the anterior horizontal ramus and gradually passing over into the orbital gyri of the inferior surface of the lobe is the ***orbital portion***, and the part behind the anterior ascending ramus forms a portion of the so-called ***operculum*** and is called the ***opercular portion***.*

By the ***operculum*** (Fig. 626) is meant all those portions of the frontal, parietal, and temporal convolutions which border on the lateral cerebral fissure and cover the gyri of the insula, which lie in the depth of the fissure. There are, therefore, distinguishable a ***frontal***, a ***temporal***, and a ***parietal portion*** of the operculum.†

The concave inferior surface of the frontal lobe has very small and generally very irregularly arranged convolutions which are collectively termed ***orbital gyri*** (Figs. 629 and 630). They are the continuation of the inferior portion of the middle frontal gyrus and of the orbital portion of the inferior frontal gyrus. Shallow furrows separate the different convolutions; a middle fissure has generally the form of an H (sulcus cruciatus); a somewhat deeper one, the ***olfactory sulcus***, contains the olfactory tract, and separates the ***gyrus rectus*** (see page 137) from the orbital gyri.

The whole mesial surface of the frontal lobe, however, does not belong to the first frontal convolution, but a portion lying above the corpus callosum belongs to the gyrus cinguli (see page 144), and a smaller portion anterior to the rostrum belongs to the rhinencephalon (see page 145). A description of the anterior central gyrus will be given in connection with the parietal lobe.

2. **The Parietal Lobe.**—The parietal lobe (Figs. 625 to 628, 631 and 632) is the middle portion of the cerebral hemisphere, bordering on all the other lobes, and including a part of the convex and a part of the flattened mesial surface of the hemisphere. Its boundaries are relatively indistinct; the one toward the frontal lobe is the *central sulcus*,‡ and the one toward the temporal lobe, the *posterior ramus of the lateral cerebral fissure*. The parietal lobe, however, extends beyond the posterior end of this fissure, so that in this region a sharp demarcation of the lobe does not exist. The same holds true of the boundary toward the occipital lobes. On the mesial surface of the hemisphere, the *parieto-occipital fissure* (Figs. 631 and 632) forms a sharp limit, but this primary fissure extends beyond the angle of the pallium only to a somewhat variable, but always short, distance upon the convex surface, so that upon that surface a sharp boundary line cannot be drawn between the occipital and parietal lobes.

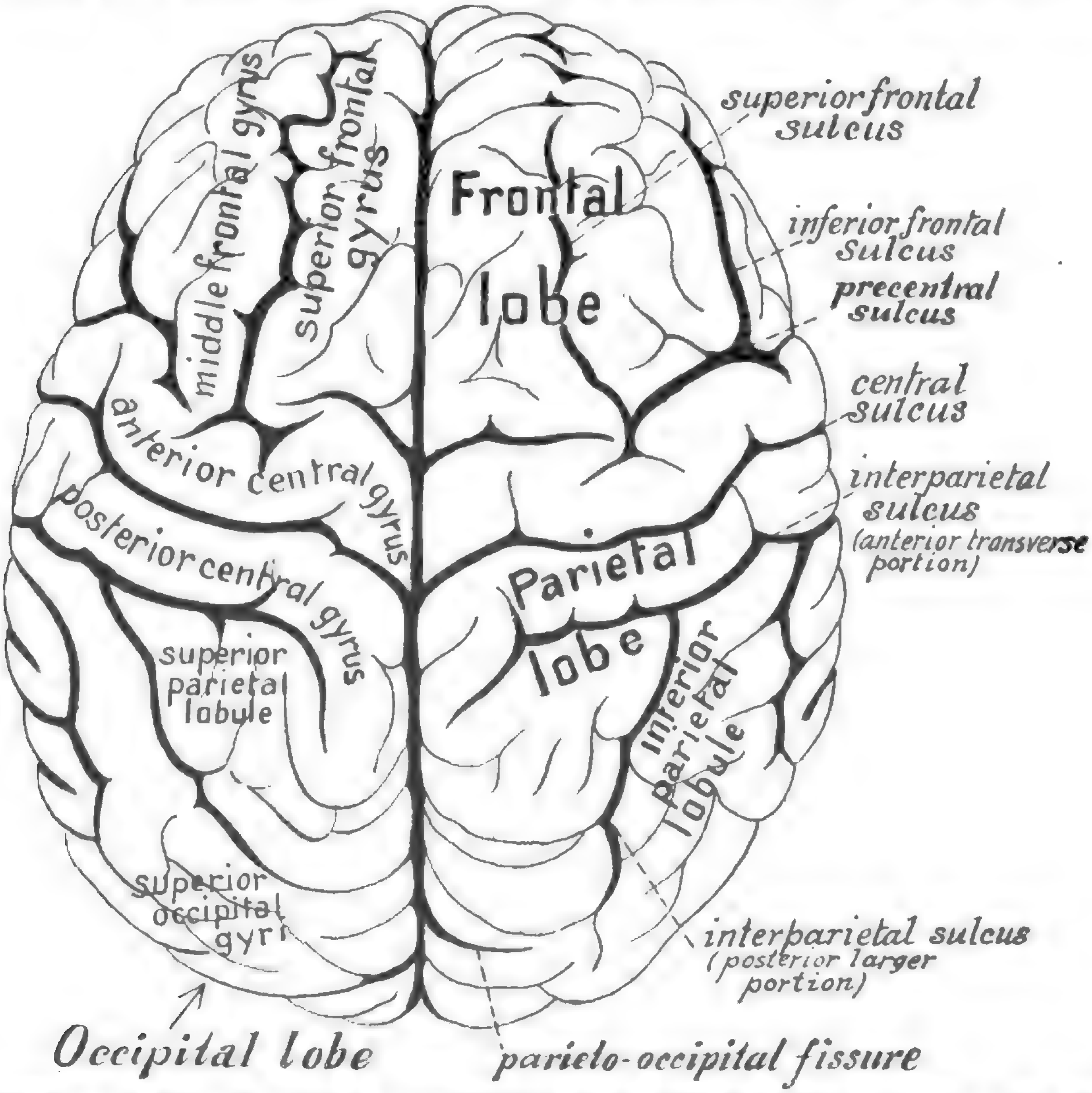
The most important fissure in the parietal region is the *central sulcus* (*fissure of Rolando*), whose course has already been described above. It separates two parallel, usually well-developed and broad convolutions. In front of the central sulcus lies the *anterior central gyrus*, which, according to the usual interpretation, belongs to the frontal lobe, and behind this is the ***posterior central gyrus***. The anterior central gyrus is separated by the ***precentral sulcus***, which in portions

* The opercular portion of the left inferior frontal gyrus contains the motor cortical center for speech (Broca's center).

† Another and preferable nomenclature regards the operculum as the portion of the cerebral hemisphere lying between the anterior and posterior rami of the lateral fissure. The operculum would then consist of a frontal portion (the opercular portion of the inferior frontal gyrus) and a parietal portion, but would include no temporal portion.

‡ If the anterior central gyrus be assigned to the parietal lobe, then the posterior boundary of that lobe will be the precentral sulcus.

of its course is incomplete, from the three frontal convolutions and, therefore, from the real frontal lobe; the posterior central gyrus has for its posterior boundary a somewhat transversely directed anterior portion of the *interparietal sulcus* (see below). At their lower ends, below the lower extremity of the central sulcus, both central gyri are united, and in this region just above the



Figs. 627 and 628.—The fissures and convolutions of the cerebral cortex as seen from above (the convex surface of the cerebral hemisphere).

lateral cerebral (Sylvian) fissure they form a part of the operculum (see page 139). They behave similarly on the mesial surface of the hemisphere, where they coalesce to form the *paracentral lobule* (see page 145).

In addition to the two central gyri the parietal lobe contains only convolutions of a sub-

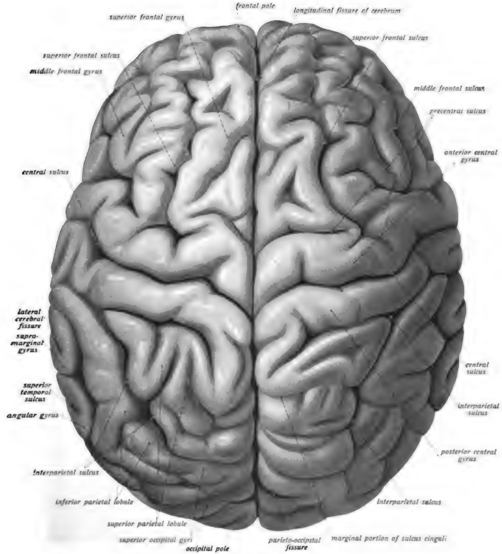

frontal pole
superior frontal gyrus
longitudinal fissure of cerebrum
superior frontal sulcus
superior frontal sulcus
middle frontal gyrus
middle frontal sulcus
precentral sulcus
anterior central gyrus
central sulcus
lateral cerebral fissure
supramarginal gyrus
central sulcus
superior temporal sulcus
interparietal sulcus
angular gyrus
posterior central gyrus
interparietal sulcus
inferior parietal lobule
interparietal sulcus
superior parietal lobule
superior occipital gyri
parieto-occipital fissure
marginal portion of sulcus cinguli
occipital pole

Fig. 628.

ordinate order, whose development and arrangement is very variable. The main fissure of the lobe—the central fissure being excepted—is the *interparietal sulcus* which determines the arrangement of the remaining gyri. This runs from the posterior surface of the posterior central gyrus, obliquely, medially and posteriorly, over the parietal lobe toward the occipital lobe, and if well developed, its posterior end extends to the *transverse occipital sulcus* of the occipital lobe. Its anterior end possesses a more or less distinctly developed cross fissure, which serves as the posterior boundary of the posterior central gyrus.

By the interparietal sulcus that portion of the convex surface of the parietal lobe which lies behind the central gyri is divided into two lobules. Above and medial to the fissure is the *superior parietal lobule*, and below and laterally the *inferior parietal lobule*, each consisting of a number of smaller, for the most part irregularly arranged, convolutions, of which two in the inferior parietal lobule have special names, namely, first, the *supramarginal gyrus*, which arches around the posterior end of the lateral (Sylvian) fissure; and secondly, the *angular gyrus* which surrounds in a similar manner the posterior end of the superior temporal sulcus. Both these gyri, and especially the supramarginal, are very variable in their development.

For the medial surface of the parietal lobe and the paracentral lobule see page 145.

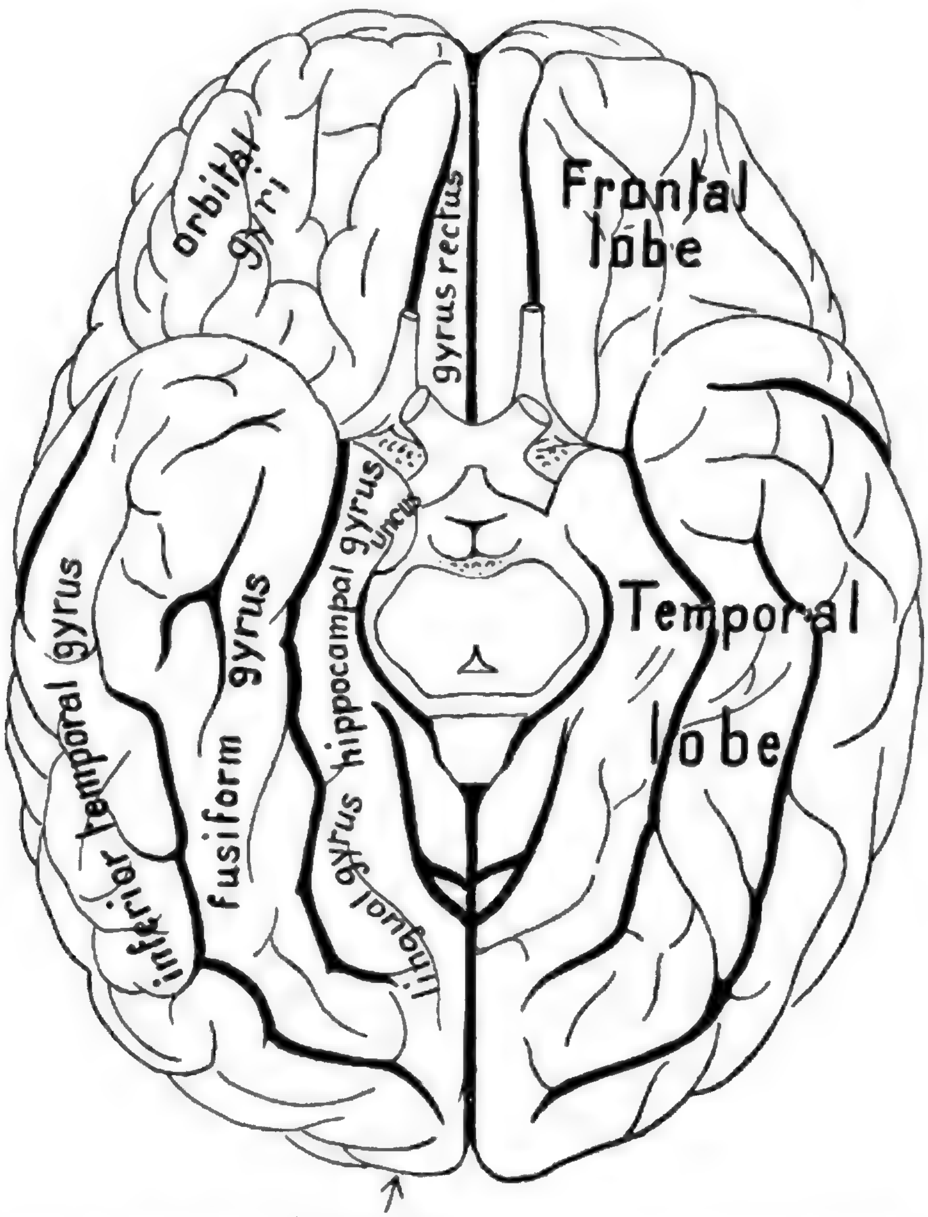
3. **The Occipital Lobe.**—The occipital lobe (Figs. 625 to 632) is the smallest of the four lobes of the hemisphere. Its form is that of a low, three-sided pyramid with rounded apex, the latter being formed by the *occipital pole*. The base of the pyramid is the plane of union with the two neighboring lobes (temporal and parietal), and of the other three surfaces, one is convex and represents the principal surface of the lobe, which forms a part of the convex surface of the hemisphere; the second is flat and forms a part of the medial surface of the hemisphere; and the third is concave and rests upon the cerebellum, or rather on the tentorium cerebelli, which here separates cerebrum from cerebellum (see page 189). The separation of the occipital from the two neighboring lobes is incomplete. It is so closely united with the temporal lobe that at the best only the *petrosal impression* can be taken as boundary line between the two (see page 136, footnote), and from the parietal lobe it is separated only on its mesial surface and in the portion of its convex surface lying lateral to the angle of the pallium by the *parieto-occipital fissure* (see page 145).

Except on the medial surface, which will be described later, the occipital lobe has only very small, unimportant, and individually very variable convolutions. Those on its convex surface are collectively known as the *superior* and *lateral occipital gyri*, the only large and fairly constant fissure found upon this surface being the almost transverse, but usually short, *transverse occipital sulcus*, which sometimes unites with the posterior end of the interparietal sulcus.

The concave inferior surface of the occipital lobe does not possess independent gyri, the sulci and gyri of the corresponding temporal surface being continued upon it.

4. **The Temporal Lobe.**—The temporal lobe (Figs. 625, 626 and 629 to 632) has an elongated, somewhat cylindrical form. It forms the lower anterior portion of the hemisphere and is the only one of the four lobes which does not come into relation with the longitudinal fissure. It is closely united to the occipital lobe, into which it gradually passes posteriorly, and while it is largely separated from the parietal lobe by the posterior ramus of the lateral cerebral fissure, it is also closely connected with it through the lateral gyri of the inferior parietal lobes (the supra-

marginal and angular gyri). Of the surfaces appearing on the hemisphere, one is convex and forms the lower anterior portion of convex cerebral surface, the second and principal surface is inferior and is concave posteriorly because of the cerebellum (see page 136) but convex



FIGS. 629 and 630.—The fissures and convolutions of the cerebral cortex as seen from below. The brain-stem and cerebellum have been removed.

anteriorly, and the third incompletely developed surface lies along the lateral cerebral (Sylvian) fissure and in the intact cerebrum cannot be seen upon the outer surface.

The main portion of the temporal lobe is divided into sagittal longitudinal gyri by distinct,

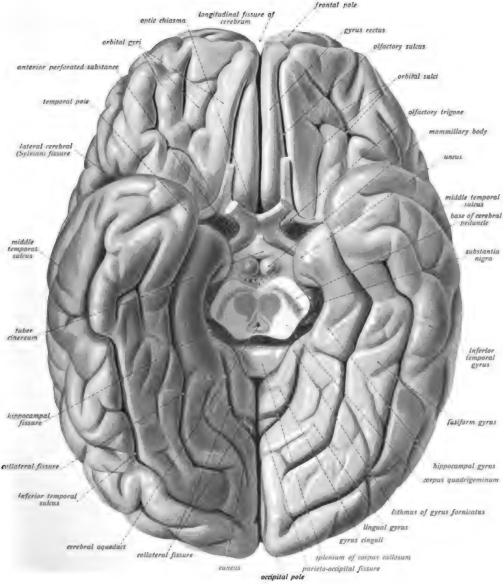

frontal pole
longitudinal fissure of cerebrum
optic chiasma
gyrus rectus
orbital gyri
olfactory sulcus
anterior perforated substance
orbital sulci
temporal pole
olfactory trigone
mammillary body
lateral cerebral (Sylvian) fissure
uncus
middle temporal sulcus
base of cerebral peduncle
middle temporal sulcus
substantia nigra
tuber cinereum
inferior temporal gyrus
hippocampal fissure
fusiform gyrus
hippocampal gyrus
collateral fissure
corpus quadrigeminum
inferior temporal sulcus
isthmus of gyrus fornicatus
lingual gyrus
cerebral aqueduct
gyrus cinguli
collateral fissure
splenium of corpus callosum
cuneus
parieto-occipital fissure
occipital pole

Fig. 630.

longitudinal fissures. These are in the first place the three *temporal sulci*, *superior*, *middle*, and *inferior*, which, together with the posterior ramus of the lateral cerebral fissure, form the boundaries of three sagittal temporal gyri which generally are well developed and quite broad. The *superior temporal gyrus* (Figs. 625 and 626) lies between the posterior ramus of the lateral cerebral fissure and the superior temporal sulcus; its most anterior point, uniting with the middle convolution, forms the *temporal pole*. The *middle temporal gyrus* (Figs. 625 and 626) lies between the superior and middle temporal sulci and is connected with the superior one posteriorly by the angular gyrus (see page 141). The superior and middle temporal gyri lie upon the lateral, inferior portion of the convex surface of the hemisphere, but the *inferior temporal gyrus* (Figs. 625, 626 and 629 to 632) occupies the rounded border between the convex lateral surface and the concave inferior surface of the temporal lobe. It lies between middle and inferior temporal sulci, the latter separating it from the fusiform gyrus.

On the concave inferior surface of the cerebral hemisphere, on which temporal and occipital lobes pass into each other without any line of demarcation, a very long sagittal fissure is found which runs almost parallel to the inferior temporal sulcus and extends as the *collateral fissure* (Fig. 632) into the region of the concave occipital surface, which in this region is not sharply divided from the temporal lobe. It corresponds to the collateral eminence of the lateral ventricle (see page 152), and together with the inferior temporal sulcus bounds a spindle-shaped convolution, the *fusiform gyrus*, which, like the collateral fissure, extends into the occipital lobe. Medial to the collateral fissure is the medial marginal portion of the lobe, which in its anterior portion is known as the *gyrus hippocampus* (see below), and in its posterior portion as the *gyrus lingualis* (Fig. 630). The latter extends into the region of the occipital lobe and is limited medially by the calcarine fissure (see below), thus lying between the collateral and calcarine fissures. Anteriorly it generally blends with the isthmus of the gyrus fornicatus. The anterior extremity of the hippocampal gyrus is curved in a hook-like manner and can be seen on the base of the brain (page 130) as a prominence known as the *uncus*. The medial boundary of the hippocampal gyrus is the hippocampal fissure, whose relation to the hippocampus will be discussed below.

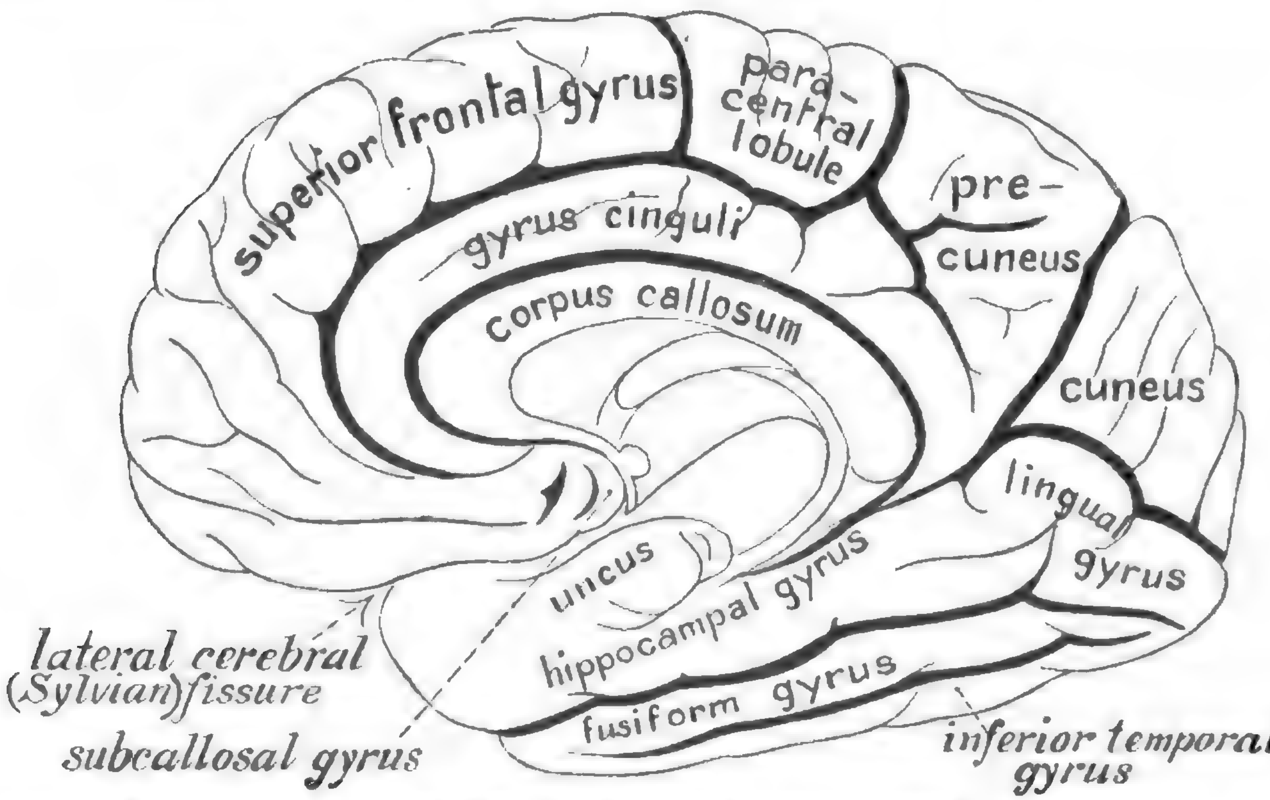
The surface of the temporal lobe bordering deeply on the lateral cerebral (Sylvian) fissure also possesses a few small convolutions and fissures. They run transversely from the region of the superior temporal convolution to the insula (see below) and, like the gyri of this, can be seen only when the borders of the Sylvian fissure are pressed apart. They are known as the *transverse temporal sulci* and *gyri* and are two, or at most three, small convolutions.

5. **The Medial Surface of the Hemisphere.**—In the formation of the flattened *medial surface* (Figs. 631 and 632) which bounds the longitudinal fissure, the frontal, parietal, and occipital lobes all take part. There are, however, a number of formations upon this surface of the hemisphere which require a separate description.

In the first place there is a fissure just above the corpus callosum, which separates the gray pallium from the white substance of the corpus callosum, and is termed the *sulcus of the corpus callosum*. It extends from the genu to the splenium and is continued on the concave inferior surface of the temporal lobe as the hippocampal fissure (see above). Parallel to this arch-like sulcus, a second one, the *sulcus cinguli*, also encircles the callosum at some distance, and, with the sulcus

of the corpus callosum, bounds a usually very broad and distinct convolution, the *gyrus cinguli*, which lies immediately above the corpus callosum. It is the anterior portion of a long arch-like convolution which extends along the medial border of the pallium and is known as the *gyrus fornicatus*. The anterior and superior portion of this is the gyrus cinguli and the lower and posterior portion the gyrus hippocampus mentioned above, the two being united behind and below the splenium of the corpus callosum by a narrow strip, the *isthmus of the gyrus fornicatus*.

The sulcus cinguli, which on the one hand forms, together with the sulcus of the corpus callosum, the boundary of the gyrus cinguli, on the other separates it from the portion of the superior frontal gyrus lying on the medial surface of the hemisphere. This anterior portion of

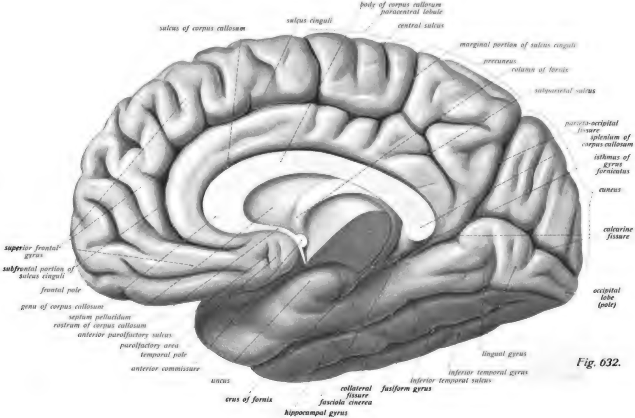


Figs. 631 and 632.—The fissures and convolutions of the cerebral cortex (mesial surface).

The brain has been bisected in the median plane and the cerebellum and brain-stem removed by a section passing obliquely through the optic thalamus.

the sulcus cinguli is called the *subfrontal portion*, and the posterior portion is termed the *marginal portion*, because it here rises above the posterior section of the body of the corpus callosum toward the angle of the pallium. Consequently, the posterior portion of the gyrus cinguli is no longer bounded above by the sulcus cinguli, but by a usually rather poorly developed fissure, variable in shape, which is termed the *subparietal sulcus* and continues the direction of the sulcus cinguli.

By the marginal portion of the sulcus cinguli ascending to the angle of the pallium and by the mesial part of the precentral sulcus, which, if well developed, may extend to the sulcus cinguli,



sulcus of corpus callosum
sulcus cinguli
body of corpus callosum
paracentral lobule
central sulcus
marginal portion of sulcus cinguli
precuneus
column of fornix
subparietal sulcus
parieto-occipital fissure
splenium of corpus callosum
isthmus of gyrus fornicatus
cuneus
calcarine fissure
occipital lobe (pole)
superior frontal gyrus
subfrontal portion of sulcus cinguli
frontal pole
genu of corpus callosum
septum pellucidum
rostrum of corpus callosum
anterior parolfactory sulcus
parolfactory area
temporal pole
anterior commissure
uncus
crus of fornix
collateral fissure
fasciola cinerea
hippocampal gyrus
fusiform gyrus
inferior temporal sulcus
inferior temporal gyrus
lingual gyrus

Fig. 632.

a special lobule, called the *paracentral lobule*, is bounded. It surrounds the medial (upper) ends of the two central gyri, which unite in this region, for although the central sulcus which separates them generally extends beyond the angle of the pallium, it does not reach the sulcus cinguli.

Behind the paracentral lobule on the medial surface of the hemisphere is a quadrangular area known as the *precuneus*. Its anterior boundary is the marginal portion of the sulcus cinguli, its posterior the parieto-occipital fissure, its superior the angle of the pallium, and its inferior the subparietal sulcus.

The *parieto-occipital fissure*, which on the medial surface forms a sharp boundary for the occipital and parietal lobes, unites in a right or acute angle behind the splenium of the corpus callosum and in the region of the isthmus of the gyrus fornicatus with the *calcarine fissure* which courses horizontally toward the occipital pole. This fissure corresponds to the calcar avis of the posterior cornu of the lateral ventricle (see page 151). The parieto-occipital and calcarine fissures bound a triangular space on the medial surface of the occipital lobe, called the *cuneus;* and just below it, and separated from it by the calcarine fissure, is the gyrus lingualis (see page 143).

The Insula (**Island of Reil**).—The insula (island of Reil) (Figs. 633, 635, 645, and 674) is a peculiar group of convolutions. It is situated in the depth of the lateral (Sylvian) fissure (see page 139) and is, therefore, in the intact brain, only visible when the borders of the fissure are widely separated. The convolutions of the insula rest directly on the large basal ganglia of the cerebral hemisphere, being separated from the lenticular nucleus only by the neighboring claustrum and the external capsule (see page 153); they are covered by the operculum (see page 139).

The insula is separated from the neighboring gyri of the operculum in front, above, and behind, by a semicircular fissure, the *circular sulcus* (sulcus of Reil), while its gyri are separated from the anterior perforated substance by a band-like elevation, the *limen insulæ*. The *central sulcus of the insula* runs obliquely from posteriorly and above to anteriorly and below, and separates the insula into an anterior and a posterior portion. The anterior portion contains generally three *short gyri*, which blend below in the pole of the insula located near the limen insulæ; the posterior section is formed by the *long gyrus* of the insula, which is usually divided in its upper portion and coalesces with the neighboring gyri of the temporal and parietal lobes.

THE RHINENCEPHALON.

To the *rhinencephalon* (Figs. 623, 624, 647, and 648) belongs the *olfactory lobe*, which is rudimentary in man, and extends along the inferior surface of the frontal lobe. It consists of the *olfactory bulb*, the *olfactory tract*, and the *olfactory trigone*. Furthermore, the *olfactory striæ* (*medial*, *intermediate* and *lateral*), the *anterior perforated substance*, the *parolfactory area* (Broca's area) and the *subcallosal gyrus* are included in the rhinencephalon.

The *olfactory bulb* (Figs. 624 and 648) is an elongated, flattened, light gray body, from which the olfactory nerves emerge. It lies upon the cribriform plate of the ethmoid and occupies the anterior end of the olfactory sulcus of the frontal lobe. Posteriorly, it is continued into the whitish *olfactory tract*, which lies in the olfactory sulcus, as a cord flattened below and slightly pointed above, and which posteriorly becomes the triangular enlargement known as the *olfactory*

FIG. 633.—The cerebral cortex as seen from the right side.

The convolutions of the insula have been exposed by removing the overlying portions of the frontal, parietal, and temporal lobes.

FIG. 634.—The entire length of the fornix exposed in its natural position.

The brain has been bisected in the median plane and the brain-stem and cerebellum removed by an oblique section through the thalamus. Enough of the hippocampal gyrus has been removed to show the fimbria and dentate fascia; the covered portion of the column of the fornix and the thalamo-mammillary fasciculus have been exposed by dissection. The specimen is viewed from below and from the inner side.

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*trigone.** This lies on the anterior border of the anterior perforated substance along the lower surface of the peduncular portion of the cerebral hemisphere (see page 154).

From the posterior end of the olfactory tract, that is to say, from the olfactory trigone, three white bands called *olfactory striæ* (Fig. 648), pass out. The middle band is very short and not always well developed; it is called the ***intermediate olfactory stria*** and sinks immediately into the anterior perforated substance. The ***lateral stria*** is the longest and runs along the border of the anterior perforated substance to the limen insulæ, with which it blends.† The ***medial stria*** curves upward upon the medial surface of the hemisphere where it terminates in the parolfactory area.

The ***parolfactory*** or ***Broca's area*** (Figs. 632 and 648) is a small gyrus lying in front of the rostral plate of the corpus callosum, and is separated from the subcallosal gyrus by the ***posterior parolfactory sulcus***, and from the superior frontal gyrus by the ***anterior parolfactory sulcus***. The latter is usually very deep and well developed and has an almost horizontal course.

The ***subcallosal gyrus*** is a narrow convolution lying between the shallow posterior parolfactory sulcus and the rostrum of the corpus callosum; on account of its relative position to the latter it was formerly designated the peduncle of the corpus callosum. Its surface is of a whitish gray color, without the reddish tinge which distinguishes the other cerebral convolutions, and generally it passes over into the anterior perforated substance without any distinct boundary. The perforated substance owes its peculiar appearance to the pores produced by the penetrating vessels; it lies at the base of the brain between the olfactory trigone, the optic tract, and the limen insulæ.

THE CORPUS CALLOSUM.

The *corpus callosum* (Figs. 624, 632, 634, 635, 646, and 648) is a large unpaired medullary mass,‡ which unites the two hemispheres as a commissure (the great cerebral commissure). It consists of transverse fibers, arranged in bundles and indicated on the surface of the corpus callosum as the transverse striæ. The corpus callosum lies at the bottom of the longitudinal cerebral fissure, of which it forms the floor, and its main portion is in an almost horizontal position. Its superior surface may be seen at the bottom of the longitudinal cerebral fissure, while its inferior surface has attached to it anteriorly the septum pellucidum and posteriorly the fornix, and its

* The upper surface of the trigone, directed toward the bottom of the olfactory sulcus, has a small enlargement, the olfactory tubercle.

† The limen insulæ does not belong to the insula, but to the rhinencephalon. It forms with the lateral olfactory stria the so-called lateral olfactory gyrus.

‡ The larger masses of white substance in the central nervous system are called medullary masses, because the nerve fibers of which they are composed are medullated, whence the white color.

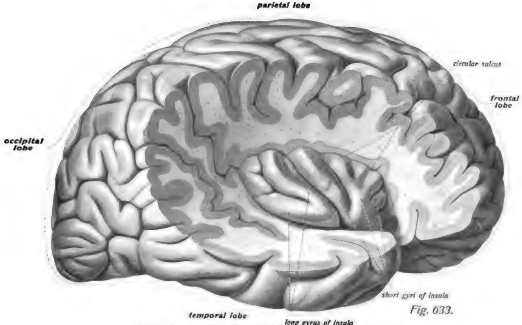

Fig. 633.

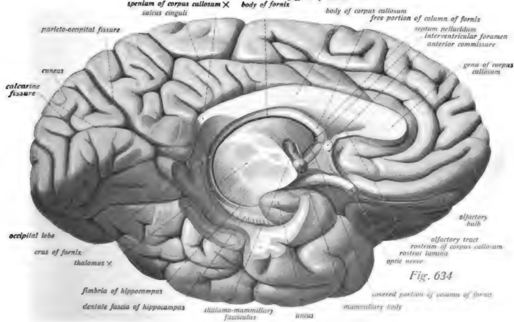

Fig. 634

body forms a part of the roof of the lateral ventricle. In the corpus callosum there may be distinguished a thick horizontal main portion, consisting of genu, body and splenium, and a much thinner vertical portion, the rostrum and rostral lamina. The surface of the thick main portion is not quite level, but is convex in the sagittal direction and consists primarily of the middle portion, the *body*, which posteriorly passes into a thickened, rounded extremity, the *splenium*. This, on account of the curvature of the corpus callosum, lies more deeply seated than the body, which has its greatest thickness in the middle of its length. Similarly, but more distinctly, the body bends downward anteriorly to form the *genu*, the most anterior point of the whole structure.

The width of the surface of the corpus callosum is somewhat greater than that of the longitudinal cerebral fissure in the region of the sulcus of the corpus callosum, which separates the gyrus cinguli from the surface of the callosum. At the bottom of this fissure, the surface of the corpus becomes continuous with the pallium. The greatest width is at the splenium, which is the only part of the corpus callosum whose lower surface is not united with other formations of the cerebrum, but, lying over the corpora quadrigemina, it forms the roof of the transverse cerebral fissure. Its most posterior point looks toward the superior vermis of the cerebellum.

The surface of the portion of the callosum lying in the depth of the longitudinal fissure in addition to the transverse striæ, also presents longitudinal ones which are thickenings of a thin layer of gray substance resting on the superior surface of the corpus callosum. Two *medial longitudinal striæ* lie parallel close to the median line, that is to say, at the bottom of the longitudinal fissure, while the *lateral longitudinal striæ* (striæ tectæ) are covered on either side by the gyrus cinguli and are connected with its gray matter. Toward the posterior region of the callosum there arises from each lateral stria a more distinct band-like structure, the *fasciola cinerea*, which terminates below the genu in the dentate fascia of the hippocampus, while the striæ pass anteriorly into the subcallosal gyrus.

Decidedly different from this portion is the much thinner vertical part lying below the genu. Immediately below the genu the corpus callosum begins to diminish rapidly in size, so that it presents an anteriorly free surface markedly concave. The portion whose posterior convex surface has united with it the septum pellucidum is called the *rostrum*. Very gradually it becomes a thin plate, the *rostral lamina*, situated in front of the anterior commissure and extending down to the lamina terminalis and laterally to the anterior perforated substance, eventually passing over into the subcallosal gyrus.

The transverse fibers which compose the corpus callosum, after their entrance into the substance of the hemisphere, radiate to all parts of the pallium and form a considerable portion of the great medullary mass of the cerebral hemisphere, the semi-oval center. The whole mass of radiations is known as the *radiation of the corpus callosum*, and a distinction is made between its anterior or *frontal portion*, uniting the two frontal lobes, its middle or *parietal portion*, passing from parietal to parietal lobe, and its posterior or *occipital* and inferior or *temporal portions*. The two latter are the longest paths; they form a large concave radiation from the splenium, passing posteriorly and inferiorly and forming the so-called major or posterior forceps, while the anterior portion, concave anteriorly, is called the minor or anterior forceps (see page 178).

That part of the posterior callosal radiation which forms the roof of the posterior and especially of the inferior cornu of the lateral ventricle, is especially designated by the name *tapetum*.

FIG. 635.—The superior aspect of the corpus callosum.

The cerebral hemispheres have been removed at the level of the centrum semiovale, and the insula has been exposed upon the right side.

FIG. 636.—The superior aspect of both lateral ventricles, the fornix, and the septum pellucidum after the partial removal of the corpus callosum.

Dissection as in Fig. 635 except that more cerebral tissue has been removed and the body of the corpus callosum cut away. Upon the left side the chorioid plexus has been divided and reflected.

THE FORNIX.

The *fornix* (Figs. 632, 634, 636 to 638, 642, 644–646, 648, and 650) consists of two strong and peculiarly bent medullary striæ, which in their middle portions lie below the corpus callosum and just above the tela chorioidea of the third ventricle. The paired character of the structure (which is paired throughout its entire development) can be easily recognized in front and behind; while in its middle portion the two striæ are fused for a relatively short distance to form the unpaired *body of the fornix*, and at the same time are fused with the inferior surface of the corpus callosum.

The fornix has three main portions: an anterior portion, the *column of the fornix*, a middle (unpaired) *body* and a posterior portion or *crus of the fornix*. The middle unpaired body is a flattened, triangular, prismatic formation, whose broader upper surface is united to the lower surface of the corpus callosum and more anteriorly also to the posterior end of the septum pellucidum, while the lateral inferior surfaces lie in the transverse fissure above the thalami and the inferior rounded broad border over the roof of the third ventricle.

Posteriorly and a little behind the middle of the corpus the two portions of the fornix separate and pass into the *crura*, becoming at the same time greatly flattened. The flat, diverging cords situated below the posterior portion of the corpus callosum diverge posteriorly and at the same time downward and laterally, and so produce a lyre-shaped figure (called the psalterium or David's lyre), the triangular interval between the two crura being occupied by a thin medullary plate, the *hippocampal commissure*, which is usually closely adherent to the inferior surface of the posterior portion of the corpus callosum.* The crura have sharp, often irregular, slightly dentate, lateral borders, called the *tæniæ of the fornix;* they are the lines of attachment of the chorioid plexus of the lateral ventricle (see below). The crura, diverging posteriorly and downward, run in the form of an arch around the posterior end of the thalamus toward the hippocampus, where they terminate, after becoming still more flattened, as the *hippocampal fimbriæ*.

Just as the body of the fornix terminates posteriorly in two diverging crura, so anteriorly it also forms the diverging *columns*. These are almost circular, cylindrical cords, which begin below the corpus callosum at the anterior portion of the body of the fornix, and run downward, forward, and laterally to the lateral wall of the third ventricle. Thus, with the anterior portion of the thalamus, they bound on either side a semilunar opening called the *interventricular foramen* or *foramen of Monro*, which is the communicating opening between the third and the lateral ventricles. In the column of the fornix two parts are distinguishable, a *free portion* and a *covered portion*, for, after a short course forward, the column enters the substance of the hypothalamus,

* Occasionally, however, it is separated from the corpus callosum by a space, the cavity of the psalterium.

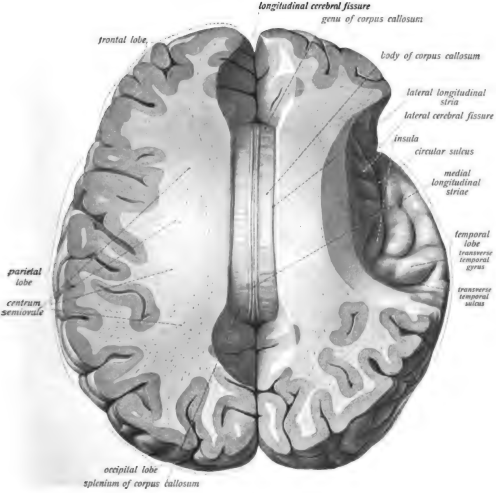
longitudinal cerebral fissure
genu of corpus callosum
frontal lobe
body of corpus callosum
lateral longitudinal stria
lateral cerebral fissure
insula
circular sulcus
medial longitudinal striae
temporal lobe
transverse temporal gyrus
transverse temporal sulcus
parietal lobe
centrum semiovale
occipital lobe
splenium of corpus callosum

Fig. 635.

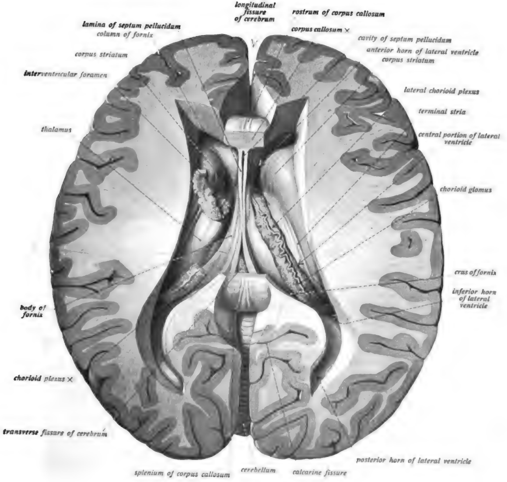
longitudinal fissure of cerebrum
rostrum of corpus callosum
lamina of septum pellucidum
column of fornix
corpus callosum ×
cavity of septum pellucidum
corpus striatum
anterior horn of lateral ventricle
corpus striatum
interventricular foramen
lateral chorioid plexus
terminal stria
thalamus
central portion of lateral ventricle
chorioid glomus
crus of fornix
inferior horn of lateral ventricle
body of fornix
chorioid plexus ×
transverse fissure of cerebrum
posterior horn of lateral ventricle
splenium of corpus callosum
cerebellum
calcarine fissure

Fig. 636.

and in it courses to the mammillary body where it terminates.* That part of the column hidden (it can easily be exposed by removal of the ependymal layer) in the substance of the wall of the third ventricle (hypothalamus) is the covered portion, the upper part, the free portion. Between the two parts of the free portion is a triangle, in which, looking at it from behind, the anterior commissure, running transversely in front of the columns, may be seen (see page 178).

The Septum Pellucidum.

The *septum pellucidum* (Figs. 624, 632, 634, and 636) is an unpaired plate, formed by two vertical and parallel thin gray lamellæ, which occupy the interval between the anterior portions of the corpus callosum (rostrum, genu, and anterior portion of body) and the fornix. The two plates which compose the septum are known as the *laminæ of the septum pellucidum;* they are separated by a slit-like sagittal cavity, the *cavity of the septum pellucidum*, which is filled with fluid and is closed above by the concavity of the genu, below by the columns and anterior portion of the body of the fornix, and anteriorly by the rostrum of the corpus callosum.

The lamina of the septum pellucidum is a rudimentary portion of the medial wall of the hemisphere and consequently bounds its cavity, the lateral ventricle. The lateral surface of each lamina is, therefore, covered by the ependyma which lines the entire cavity of the ventricle.

The Lateral Ventricle.

The *lateral ventricle* (Figs. 636 to 641) is a peculiarly curved cavity which extends throughout the greater portion of each hemisphere. It lies much closer to the medial than to the lateral surface of the hemisphere, indeed, in places, its medial boundary is only epithelial in character. Furthermore, the whole lateral ventricle lies in the lower half of the hemisphere, since its highest point is below the level of the inferior surface of the corpus callosum, the upper half of the hemisphere being solid and containing the large medullary mass of the semioval center. Normally, the width of the ventricle is but slight, although certain portions are wider than others.

In each lateral ventricle four indistinctly separated portions are recognized, one of which belongs to each of the four lobes. The middle part, from which all others arise, is in the region of the parietal lobe and is called *central* portion (cella media). From it three projections are given off, the *cornua* of the ventricles, which penetrate more or less deeply into the three other lobes. The *anterior cornu* (Figs. 637 to 639) extends forward and at the same time downward and laterally into the frontal lobe, and is quite wide, but short, scarcely reaching to the genu. Posteriorly the *posterior cornu* (Figs. 637 to 640) projects from the central portion; it is a rather short prolongation, curving posteriorly and medially, the sharp point in which it terminates lying considerably behind the splenium of the corpus callosum. The longest and also the narrowest prolongation of the lateral ventricle is the *inferior cornu* (Figs. 636 to 642), which follows the curvature of the temporal lobe, that is to say, it bends around the brain stem, downward and forward, to the uncus.

Since the walls of the various portions of the lateral ventricle are formed by different, and to a certain extent important, structures of the brain, it will be well to consider the portions separately.

* [The course of the column is at first downward in the substance of the lamina terminalis and then backward in the hypothalamic portion of the hemisphere.—Ed.]

FIG. 637.—The superior aspect of both lateral ventricles and of the third ventricle.

The body and splenium of the corpus callosum, the body of the fornix, and the tela chorioidea of the third ventricle have been removed. The hemispheres have been divided horizontally just below the level of the corpus callosum, the left temporal lobe cut away as far as the tip of the inferior horn, and a sound passed through the interventricular foramen.

FIG. 638.—The lateral ventricle, the corpus callosum, and the tela chorioidea of the third ventricle.

Dissection as in Figs. 636 and 637, except that the corpus callosum has been divided with the fornix and reflected forward and backward (after dividing the septum pellucidum), exposing the transverse cerebral fissure and the tela chorioidea of the third ventricle.

FIG. 639.—The posterior and inferior horns of the lateral ventricle.

Dissection as in Fig. 637.

The **anterior cornu** (Figs. 636 and 637, 642 to 646, 674, and 675) is bounded anteriorly, superiorly, and to a large extent inferiorly by the anterior radiation of the corpus callosum. Its medial wall is formed by the lamina of the septum pellucidum, while the lateral wall and the portion of the inferior wall bordering upon it is formed by a strong gray eminence, the *corpus striatum*, which projects into the cavity of the ventricle and is one of the large ganglia of the hemisphere (see below). Its thickened end lying in the anterior cornu contains the *head of the caudate nucleus* (see below) and is therefore called the *head of the corpus striatum.*

The **central portion** of the lateral ventricle (Figs. 636 and 637) is a narrow, almost horizontal fissure, which does not lie exactly sagitally, but has its long axis directed from before and medially, posteriorly and laterally. Its upper wall is also formed by the callosal radiation (the parietal part) and its lower wall is the for the most part poorly developed, original medial wall of this part of the cerebral vesicle. On account of the shallowness of the cavity, the side walls cannot be distinguished unless it be in the most anterior portion, directly in front of the interventricular foramen, where the posterior part of the lamina of the septum pellucidum forms a low, mesial wall. In the floor of the central portion there is to be found in the first place, in the anterior part, the sickle-shaped interventricular foramen, which leads into the third ventricle and is bounded by the columns of the fornix (see page 148). The lateral portion of the floor, so far as one can speak of a lateral portion because of the shallowness of the space, is, as in the anterior cornu, occupied by the now comparatively thin corpus striatum (that is to say, the caudate nucleus), and along its mesial border runs a fairly large, bluish band, the *terminal stria*, a thickening of the ventricular ependyma, below which lies the terminal vein (see page 88), this causing the bluish tinge. The terminal stria is the boundary between the thalamus, that is to say, the diencephalon and the corpus striatum, that is to say, the telencephalon.* Medial to this, in the floor of the ventricle, is a part of the surface of the thalamus, which, however, is not actually a portion of the floor, since it belongs to the diencephalon and is covered by a thin plate, the rudimentary medial wall of the cerebral vesicle, the so-called *lamina affixa*, which is firmly adherent to the superior surface of the thalamus, passing laterally into the terminal stria and medially into a thin, slightly dentate plate, which is continued into the epithelial chorioid lamina. Medial from the thalamus in the floor of the ventricle is the chorioid plexus, which is formed mainly by the pia mater and contains a plexus formed by its vessels. The ventricular surface of the plexus is covered only

* Below the terminal stria is the intermediate sulcus, which marks the separation of the thalamus and corpus striatum, which are fused in this region.

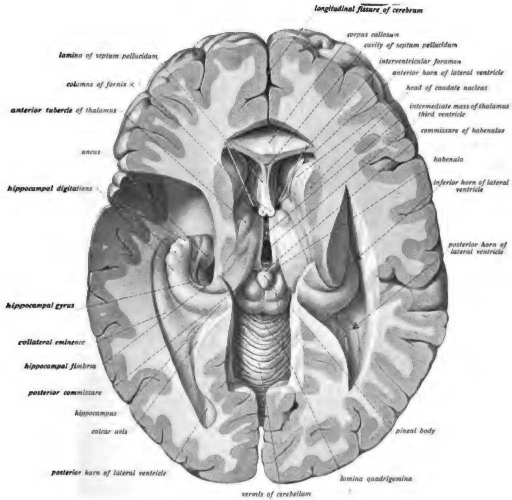
longitudinal fissure of cerebrum
corpus callosum
cavity of septum pellucidum
lamina of septum pellucidum
interventricular foramen
anterior horn of lateral ventricle
columns of fornix ×
head of caudate nucleus
anterior tubercle of thalamus
intermediate mass of thalamus
third ventricle
commissure of habenulae
uncus
habenula
hippocampal digitations
inferior horn of lateral ventricle
posterior horn of lateral ventricle
hippocampal gyrus
collateral eminence
hippocampal fimbria
posterior commissure
hippocampus
calcar avis
pineal body
posterior horn of lateral ventricle
lamina quadrigemina
vermis of cerebellum

Fig. 637.

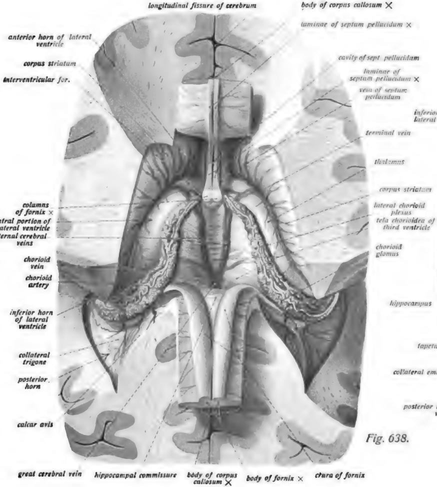

Fig. 638.

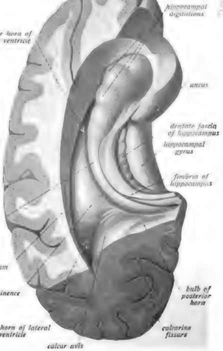

Fig. 639.

by a simple, microscopic epithelial layer, the ***epithelial chorioidal lamina***, which represents the medial wall of the cerebral vesicle persisting in its embryonic epithelial condition.* Laterally this epithelial lamella becomes the sharpened border of the lamina affixa, the ***chorioidal tænia***, and medially it passes over into the border of the fornix, the *tænia of the fornix*. Medial to the chorioid plexus the floor of the central portion of the ventricle is formed by the fornix.

The **posterior cornu** (Figs. 637 to 639) has a rather variable length, since its medially directed point extends sometimes to a greater and sometimes to a lesser distance from the pole of the occipital lobe. Its root is also formed by the callosal radiation and the lateral wall by the portion of the radiation known as the *tapetum*, while another part of the radiation often forms a white projection from the upper portion of the medial wall of the horn, termed the ***bulb of the posterior horn***. Below this is a constant rounded projection of the mesial wall known as the *calcar avis*. It is caused by the calcarine fissure, which penetrates deeply into the substance of the posterior horn and with its anterior portion directly touches the hippocampus and also the collateral eminence, both of which structures really belong to the inferior cornu.

The **inferior cornu** (Figs. 637, 639 to 641) is bounded laterally by the tapetum, which also forms part of the upper wall. It contains the continuation of the lateral chorioidal plexus,† which does not extend into the posterior cornu, but presents quite a pronounced enlargement, the ***chorioid glomus***, at the junction of the inferior cornu with the central portion of the ventricle, but quickly flattens toward the end of the inferior cornu. It forms only part of the medial wall of the ventricle, for its epithelial lamina gradually becomes nerve tissue, passing over into the direct extension of the tænia of the fornix, into the tænia of the fimbria on the one side, and into the chorioid tænia of the terminal stria on the other side, this latter being continued along the tail of the caudate nucleus into the mesial wall of the inferior cornu (see page 153). If the chorioid plexus is removed from the lateral ventricle the epithelial chorioidal lamina is of course torn from its places of attachment and an artificial cleft, the *chorioidal fissure*, is produced in the medial wall of the inferior cornu and in the floor of the central portion of the ventricle.

The most noticeable structure of the inferior horn lies upon its floor and is the ***hippocampus*** (also known as the cornu ammonis), a retort-like swelling concave on its medial surface and of a white color on its ventricular surface. Its anterior portion is very thick and presents several (three to four) ***digitations*** and in this region it passes directly into the uncus (hippocampal gyrus). Its posterior end is flat and gradually passes into the hippocampal commissure, lying below the splenium of the corpus callosum (see page 147). Along its medial concave border and united to it runs a white band, the ***hippocampal fimbria***, the decidedly flattened, direct prolongation of the crus of the fornix. Its white fibers spread out over the deeper gray substance so that it gradually but entirely disappears toward the anterior extremity of the horn.

The hippocampus corresponds on the external surface of the brain to the hippocampal sulcus, since the hippocampus is to be regarded as an invagination of the ventricular wall, as may easily be recognized in microscopic and even in macroscopic frontal sections (see below).

* The mesial wall of the vesicle develops but very little nerve tissue in this region, laterally and below only the lamina affixa, medially (above) the fornix. Between these two is the purely epithelial chorioidal lamina, throughout which there is no development of nerve tissue.

† The chorioid plexus is only apparently in the ventricle; it merely projects into it and is always covered by the epithelial ventricular lining. It has the same relation to the ventricle as the intestine has to the peritoneal cavity.

In addition to the hippocampus the floor of the inferior cornu presents a strong, flat, triangular area, lying between the convex surface of the hippocampus and the calcar avis, and termed the *collateral trigone;* it corresponds to the collateral fissure of the temporal lobe. Just as this fissure and the gyrus lingualis bounded by it (see page 143) belong both to the occipital and to the temporal lobe, so too the collateral trigone forms a part of the floor of the posterior, as well as of the inferior cornu. Its strongest projection, which however is not always very distinct, is termed the *collateral eminence.*

The *dentate fascia* of the hippocampus (Figs. 634 and 639 to 641) a very variably developed and usually distinctly dentate band, is connected to the hippocampal fimbria medially and is largely covered by it; it does not actually lie in the wall of the inferior cornu,* but may be seen from the ventricle after removal of the chorioid plexus. It is a rudimentary gyrus belonging to the temporal lobe and is a direct continuation of the fascia cinerea (see page 147). Laterally the dentate fascia (dentate gyrus) borders upon the hippocampal gyrus, and is located between it and the hippocampus itself, as may be seen in frontal sections, in which the hippocampus appears as a coiled portion of the ventricular wall (Figs. 642 and 646).

The white medullary lamina which forms the ventricular surface of the hippocampus is called the *alveus,* and its fibers have their origin in the hippocampal fimbria. The hippocampal gyrus, in contrast to the other convolutions, is also covered on its medial surface by a thin white layer of fibers, the *reticular white substance* (of Arnold). This penetrates into the substance of the hippocampus and makes its appearance as the rolled-up medial border of the wall of the hemisphere even more distinct.

THE SEMI-OVAL CENTER AND THE GRAY GANGLIA OF THE HEMISPHERE.

While the ventricular cavity of the cerebrum, as well as the neighboring large gray ganglionic masses, are situated below the level of the corpus callosum, the semi-oval center surrounded by the cortical gray substance shows its greatest development in the upper part of the hemisphere at the level of the superior surface of the corpus callosum. A horizontal section made through this region will show this center (the center of Vieussens) as a large white area surrounded by a simple layer of gray cortex (Fig. 635). Its fibers are largely radiations from the corpus callosum, but it also contains numerous fiber tracts which are prolongations of those found in the brain stem and belong to the so-called *corona radiata* (see page 178). Finally, it contains also numerous smaller tracts, such as association bundles, etc. (see page 176).

Masses of gray substance, independent of the gray cortex, occur in the deeper parts of each cerebral hemisphere in the form of large ganglia. There are four of these which are all close together, the first three especially so: 1. The *caudate nucleus;* 2, the *lenticular nucleus;* 3, the *claustrum;* 4, the *amygdaloid nucleus,* which last has but slight relations to the other three.

The *caudate nucleus* (Figs. 641 to 646, 674, and 675) is an elongated, curved ganglion, remarkably enlarged at its anterior extremity and constitutes the medial main portion of the corpus striatum. Its most anterior, thickened portion is the *head* and forms the projection of the corpus striatum into the anterior horn of the lateral ventricle (head of the corpus striatum, see page

* The dentate fascia is really extraventricular, since the tænia of the fimbria becomes continuous with the epithelial lamina. The cavity of the ventricle is closed by the epithelial lamina above the dentate fascia.

150); it is situated in the frontal lobe and bends anteriorly and downward. The middle portion of the retort-like ganglion is decidedly convex upward and is the *body;* it is located in the parietal lobe and also causes a corresponding bulging of the wall of the central portion of the lateral ventricle (the body of the corpus striatum). The very slender tail bends posteriorly and downward in the temporal lobe and does not form any protuberance in the ventricular wall. On account of the great curvature of the nucleus the tip of the tail lies only a short distance from the posterior end of the head, although on a lower plane.

The *lenticular nucleus* (Figs. 641 to 646, 674, and 675) constitutes the lateral portion of the corpus striatum, and in contrast to the caudate nucleus it does not reach to the ventricular wall, but lies between the thalamus and caudate nucleus on the medial side and the insula laterally, and is below the level of the floor of the central portion of the ventricle. Its shape is that of a three-sided prism with curved surfaces and its length is about twice its width. In a frontal section it appears as an equilateral triangle while in horizontal section it is a scalene triangle. Its longest side is the lateral convex one which faces the insula and is separated from it not only by the claustrum, but also by the external capsule (see below). The anterior mesial surface is shorter than the posterior one and is almost straight; it is separated by the anterior limb of the internal capsule from the tail of the caudate nucleus. The posterior mesial surface is in relation to the thalamus and partly also to the hypothalamus and tail of the caudate nucleus * from which it is separated by the posterior limb of the internal capsule.

The lenticular nucleus lies in the curvature of the caudate nucleus in such a manner that the internal capsule incompletely separates the two nuclei, which together form the corpus striatum, and the lower end of the head of the caudate nucleus passes directly over into the anterior end of the lenticular nucleus, the internal capsule being lacking in this region. Below this nucleus is the anterior perforated substance, the anterior commissure and a portion of the brain stem. The substance of the nucleus is divided into three parts, two smaller medial and a large lateral portion, by fine medullated laminæ, running almost sagittally and readily distinguishable in a fresh brain on account of their color. The lateral portion, which surrounds the other two as with a mantle, is called the *putamen;* it is of a decidedly darker gray color than the other two parts, which together are known as the *globus pallidus.*

The *claustrum* (Figs. 641 to 646, 674, and 675) is a narrow, almost vertical, thin plate of gray substance which lies close to the lateral convex surface of the putamen. From this it is separated by a thin plate of medullated fibers, the *external capsule*, while with its opposite (lateral) surface, it is in immediate relation with the convolutions of the insula. The surface is slightly dentated in correspondence with the surface form of the insular convolutions, from whose gray cortex the claustrum is separated only by a narrow band of white substance.

The *amygdaloid nucleus* (Fig. 644) is a rounded mass of gray substance lying in the anterior end of the temporal lobe in the vicinity of the uncus, in front of the anterior end of the inferior cornu of the lateral ventricle. It is united with the gray substance of the temporal lobe and lies below the anterior end of the lenticular nucleus, from which it is separated by a prolongation of the external capsule.

* The lenticular nucleus is a part of the telencephalon, while the thalamus belongs to the diencephalon. The two parts, however, are united by the fibers of the internal capsule (see page 154).

FIG. 640.—A transverse section of the anterior extremity of the temporal lobe after opening the inferior horn (as in Figs. 638 and 639). View from behind and from above.

FIG. 641.—A frontal transverse section of the temporal lobe and of the contiguous portions of the inter-brain and midbrain.

The pia mater with the blood-vessels has been retained. * · A small arterial twig.

FIG. 642.—An anterior view of a section of the brain in the plane of the cerebral peduncles.

The section through the left cerebrum is more posterior than that through the right.

FIG. 643.—A frontal section of the brain in the region of the anterior portion of the septum pellucidum.

The anterior cut surface is viewed from behind.

FIG. 644.—A frontal section of the brain in the region of the anterior commissure.

The anterior cut surface is viewed from behind.

The broad white layer of fibers, lying between lenticular nucleus on one side and the caudate nucleus and thalamus on the other (see above) is known as *internal capsule.* In it may be recognized two limbs, which unite at an angle in the horizontal plane. The anterior limb or *frontal portion* lies between the head of the caudate nucleus and the anterior medial surface of the lenticular nucleus; the posterior limb or *occipital portion* is between the posterior medial surface of the lenticular nucleus and the thalamus. At the place of junction of the two limbs a right or slightly obtuse angle, open laterally, the *genu of the internal capsule,* is formed.*

The portion of the hemisphere which contains the large ganglia of the corpus striatum and the claustrum, and whose surface bears the insular convolutions, is termed the peduncular portion, or it is the direct continuation of the brain stem and especially of the mesencephalon. The whole corpus striatum (caudate nucleus and lenticular nucleus), therefore, is known as the *basal ganglion* and the insular convolutions, in contrast to the gyri of the pallium, as the *basal gyri.*

The Optic Portion of the Hypothalamus.

To the optic portion of the hypothalamus (Figs. 624, 644, 645, and 647 to 649), which represents the unpaired portion of the telencephalon, belong: 1, The *lamina terminalis;* 2, the *optic chiasma* with the optic tracts; 3, the *tuber cinereum;* 4, the *infundibulum;* 5, the *hypophysis.*

The *lamina terminalis* (Figs. 624, 647, and 648) is a very thin lamina, ascending almost vertically in front of the optic chiasma and forming the anterior wall of the third ventricle. Before the complete development of the cerebral vesicle it represented the anterior end of the telencephalon (see page 125). Above, it passes over into the rostral lamina of the corpus callosum, laterally into the hemispheres and, with the optic chiasma, it forms the *optic recess* of the third ventricle.

The *optic chiasma* (Figs. 624, 644, 647 to 649) is a flattened, white, quadrangular body, from whose anterior inferior angles the optic nerves arise, while from its posterior upper ends the optic tracts extend posteriorly and laterally, so that it is the central portion of a St. Andrew's cross (X). The flat optic tracts run along the medial posterior border of the anterior perforated substance toward the metathalamus (see page 158).

The *tuber cinereum* (Figs. 630, 647 to 649) is a large, convex elevation lying in the floor of

* A part of the internal capsule lies also between the lenticular nucleus and the hypothalamus. This is, therefore, termed *subthalamic region of the internal capsule* in contrast to the *thalamic region,* which is the main portion between the thalamus and the lenticular nucleus.

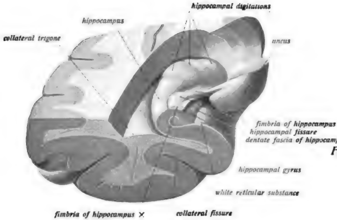

Fig. 640.

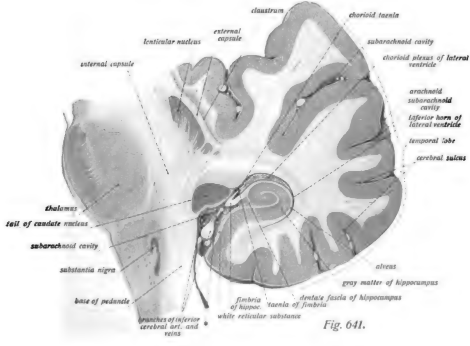

Fig. 641.

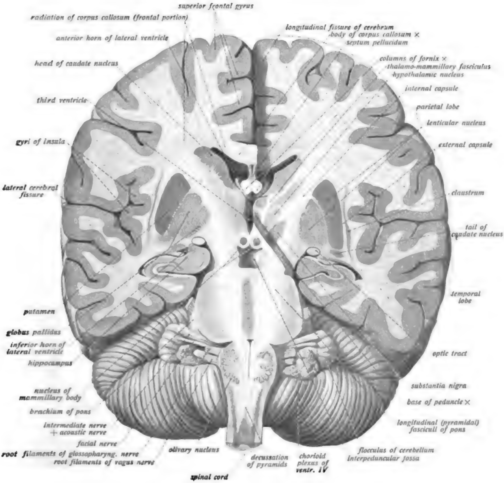
superior frontal gyrus
radiation of corpus callosum (frontal portion)
longitudinal fissure of cerebrum
body of corpus callosum ×
septum pellucidum
anterior horn of lateral ventricle
head of caudate nucleus
columns of fornix ×
thalamo-mammillary fasciculus
hypothalamic nucleus
internal capsule
third ventricle
parietal lobe
lenticular nucleus
gyri of insula
external capsule
lateral cerebral fissure
claustrum
tail of caudate nucleus
temporal lobe
putamen
globus pallidus
inferior horn of lateral ventricle
hippocampus
optic tract
substantia nigra
nucleus of mammillary body
base of peduncle ×
brachium of pons
longitudinal (pyramidal) fasciculi of pons
intermediate nerve + acoustic nerve
facial nerve
flocculus of cerebellum
interpeduncular fossa
root filaments of glossopharyng. nerve
root filaments of vagus nerve
olivary nucleus
decussation of pyramids
chorioid plexus of ventr. IV
spinal cord

Fig. 642.

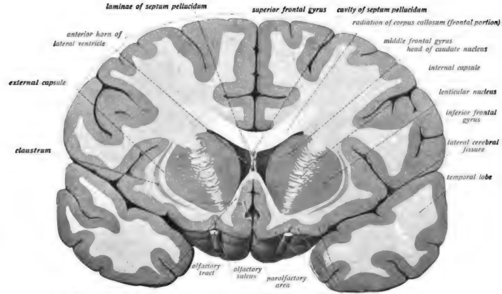

Fig. 643.

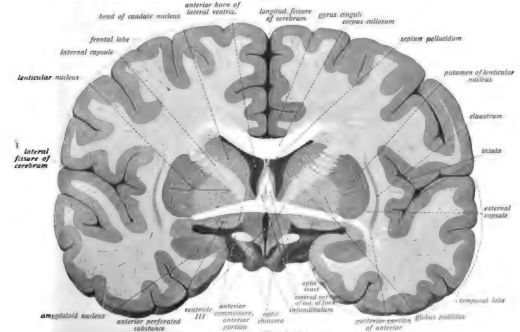

Fig. 644.

the third ventricle and is formed by a thin soft plate which anteriorly passes directly into the lamina terminalis and posteriorly is continued downward as a funnel, called the infundibulum. In addition to gray substance it has also transverse fiber tracts such as the *inferior* (Gudden's) *commissure* running just behind the optic chiasma and the large *superior* (Meynert's) *commissure.*

The *infundibulum* (Figs. 624, 645, 647 to 649) is a hollow prolongation of the gray substance of the tuber cinereum directed anteriorly and downward, and passes over into the posterior lobe of the hypophysis. Its cavity is called the *infundibular recess* and is a prolongation of the third ventricle.

The *hypophysis* (Figs. 623, 624, and 648) is a flattened, spherical, grayish-red body which is attached to the base of the brain only by the infundibulum, being otherwise quite free. It lies in the hypophyseal fossa in the sella turcica of the sphenoid, is flattened anteroposteriorly, and is about as large as a medium-sized bean. It consists of two parts which are quite different in color and structure, but are closely united and are called the *lobes*. Only the smaller *posterior lobe* is a part of the brain; the larger *anterior lobe* is formed from the epithelium of the primitive oral sinus (see Vol. II., page 21), which has no nervous constituents.

THE DIENCEPHALON.

The *diencephalon* (Figs. 637, 639, 642 to 646, 648, 674, and 675) includes the boundaries of the greater portion of the third ventricle, namely, the mammillary portion of the hypothalamus and the thalamencephalon. The latter is again divided into thalamus, epithalamus, and metathalamus.

The *third ventricle* (Figs. 624, 637, 642, and 644 to 648) does not lie entirely in the diencephalon since its lower portion is bounded by the hypothalamus and, therefore, really belongs to the telencephalon; the greater portion of it, however, belongs to the diencephalon. It is unpaired and has the form of a sagittal fissure, being exceedingly narrow from side to side. In its anterior portion it is in communication on either side with the lateral ventricles by the *interventricular foramen*, and posteriorly it is continuous with the cavity of the mesencephalon, the cerebral aqueduct. Its greatest width is in its posterior portion and even here it is but slight; anteriorly, the ventricle is much higher than posteriorly.

The lateral walls of the third ventricles are formed on either side by the medial surfaces of the optic thalamus and hypothalamus. These two regions are separated by an almost horizontal groove, running from the vicinity of the interventricular foramen to the entrance of the aqueduct and known as the *hypothalamic sulcus* (sulcus of Monro). The anterior wall of the ventricle is formed below by the *lamina terminalis* and higher up by the *rostral lamina* of the corpus callosum and the *anterior commissure*, which appears for a short portion of its course as a rounded bundle in the anterior wall of the third ventricle, lateral to which are the *columns of the fornix*. The floor is formed anteriorly by the *optic chiasma*, more posteriorly by the *hypophysis* with the infundibulum, which are portions of the optic portion of the hypothalamus, while the most posterior portion is formed by the mammillary portion of the hypothalamus with the *corpora mammillaria* and the *posterior perforated substance.** The posterior wall presents the entrance to the cerebral aqueduct, and above it is the *epithalamus*, composed of the *posterior commissure*, the *habenula* and the *pineal*

* The anterior parts of the cerebral peduncles also take part in the boundary of the third ventricle.

FIG. 645.—A frontal section of the brain through the anterior extremity of the third ventricle just behind the anterior commissure.

The anterior cut surface is viewed from behind.

FIG. 646.—A frontal section of the brain through the middle of the third ventricle.

The anterior cut surface is viewed from behind.

FIG. 647.—The structures at the base of the brain (somewhat enlarged).

The anterior extremities of both temporal lobes have been removed, the optic nerves cut off close to the chiasma, and a piece of the left optic tract removed. Upon the left side the emerging roots of the nerves have been left *in situ*; upon the right they have been removed.

FIG. 648.—A median section of the human brain without the hemispheres.

* = Tuber cinereum. ** = Tela chorioidea. + = Chorioid plexus of fourth ventricle.

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body. The roof is epithelial in character, being represented by an *epithelial chorioidal lamina* and a *tela chorioidea*. Here, as in the neighboring medial surfaces of the cerebral vesicles, no formation of nerve tissue takes place, but instead the epithelial covering of the ventricle lies close to the inferior surface of the pia mater which occupies the transverse fissure. It is this double leaflet of pia mater lying between the inferior surface of the corpus callosum and fornix on one side and the superior surface of the diencephalon on the other, that is to say, lying in the transverse cerebral fissure, that forms the tela chorioidea of the third ventricle. Since it occupies the whole breadth of the fissure, it is closely connected, laterally, with the chorioid plexus of the lateral ventricle. Its ventral lamina forms short villus-like processes covered by the epithelial lamina and projecting into the cavity of the third ventricle, forming its *chorioid plexus*. The epithelial lamina of the tela chorioidea is attached on either side to a sharp, often slightly dentate border of the thalamus, the *tænia thalami*, passing over along this line into the lateral wall of the ventricle, which consists of nerve tissue. Between the two laminæ of the tela chorioidea the internal cerebral veins have their course, uniting posteriorly (see page 88) to form the great cerebral vein.

In the cavity of the third ventricle a number of diverticula known as *recesses* occur. In the first place the optic chiasma projects dorsally in the deepest portion of the floor in such a manner as to divide it into the anterior *optic recess*, lying between the lamina terminalis and the chiasma, and the more posterior *infundibular recess*, lying in the tuber cinereum and infundibulum. Furthermore, between the diverging free portions of the columns of the fornix and the anterior commissure, there is a usually shallow evagination of the anterior wall, known as the *triangular recess*, and two evaginations occur in the region of the epithalamus. One of these, the *pineal recess*, extends to the pineal gland, the other, the *suprapineal recess*, is above it in the posterior portion of the epithelial chorioidal lamina, which bounds it superiorly. Finally, the cavity of the third ventricle gradually goes over into the cavity of the mesencephalon through the opening of the cerebral aqueduct.

THE THALAMENCEPHALON.

The thalamencephalon is formed largely by the thalamus, from which it derives its name, but partly also by the structures of the epithalamus (the pineal body and pineal stalk) and the geniculate bodies of the metathalamus.

The *thalamus* (*optic thalamus*) (Figs. 634, 636 to 638, 645, 646, 648, 650, 660, and 674) is an elongated, oval body with a flattened medial surface, whose anterior portion is the smaller,

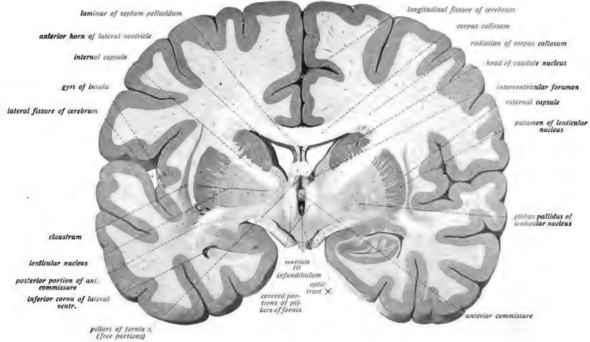
laminae of septum pellucidum
anterior horn of lateral ventricle
internal capsule
gyri of insula
lateral fissure of cerebrum
claustrum
lenticular nucleus
posterior portion of ant. commissure
inferior cornu of lateral ventr.
pillars of fornix × (free portions)
ventricle III
infundibulum
optic tract ×
covered portions of pillars of fornix
longitudinal fissure of cerebrum
corpus callosum
radiation of corpus callosum
head of caudate nucleus
interventricular foramen
external capsule
putamen of lenticular nucleus
globus pallidus of lenticular nucleus
anterior commissure

Fig. 645.

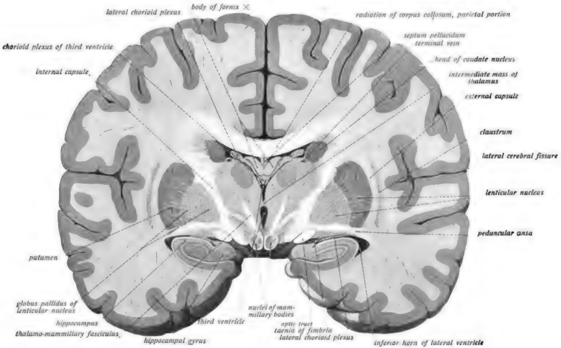
lateral chorioid plexus
body of fornix ×
radiation of corpus callosum, parietal portion
chorioid plexus of third ventricle
septum pellucidum
terminal vein
internal capsule
head of caudate nucleus
intermediate mass of thalamus
external capsule
claustrum
lateral cerebral fissure
lenticular nucleus
peduncular ansa
putamen
globus pallidus of lenticular nucleus
hippocampus
thalamo-mammillary fasciculus
hippocampal gyrus
third ventricle
nuclei of mammillary bodies
optic tract
taenia of fimbria
lateral chorioid plexus
inferior horn of lateral ventricle

Fig. 646.

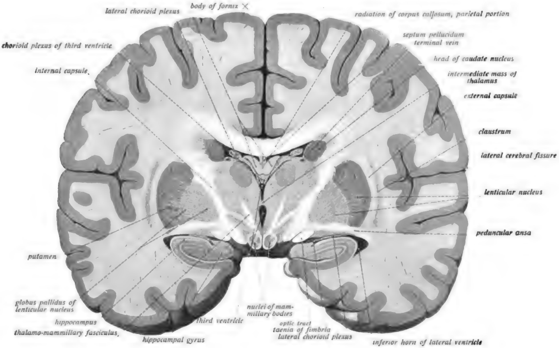
lateral chorioid plexus
body of fornix ×
radiation of corpus callosum, parietal portion
chorioid plexus of third ventricle
septum pellucidum
terminal vein
head of caudate nucleus
internal capsule
intermediate mass of thalamus
external capsule
claustrum
lateral cerebral fissure
lenticular nucleus
peduncular ansa
putamen
globus pallidus of lenticular nucleus
hippocampus
thalamo-mammillary fasciculus
hippocampal gyrus
third ventricle
nuclei of mammillary bodies
optic tract
taenia of fimbria
lateral chorioid plexus
inferior horn of lateral ventricle

Fig. 646.

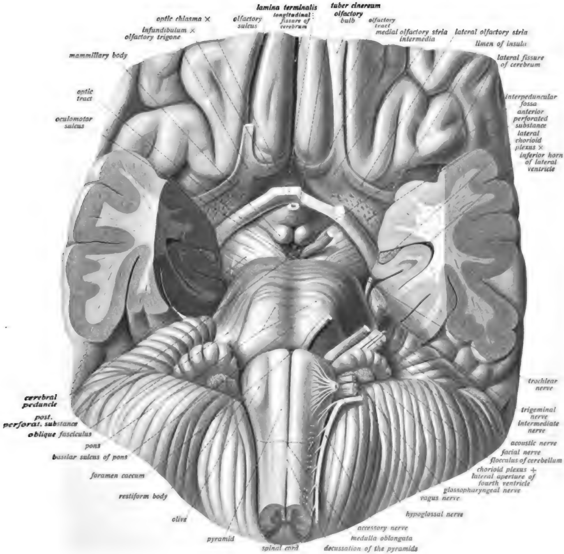
lamina terminalis
tuber cinereum
optic chiasma ×
olfactory sulcus
longitudinal fissure of cerebrum
olfactory bulb
olfactory tract
infundibulum ×
olfactory trigone
medial olfactory stria
intermedia
lateral olfactory stria
limen of insula
mammillary body
lateral fissure of cerebrum
optic tract
interpeduncular fossa
anterior perforated substance
oculomotor sulcus
lateral chorioid plexus ×
inferior horn of lateral ventricle
trochlear nerve
cerebral peduncle
trigeminal nerve
post. perforat. substance
intermediate nerve
oblique fasciculus
pons
acoustic nerve
basilar sulcus of pons
facial nerve
flocculus of cerebellum
foramen caecum
chorioid plexus +
lateral aperture of fourth ventricle
glossopharyngeal nerve
restiform body
vagus nerve
hypoglossal nerve
olive
accessory nerve
pyramid
medulla oblongata
spinal cord
decussation of the pyramids

Fig. 647.

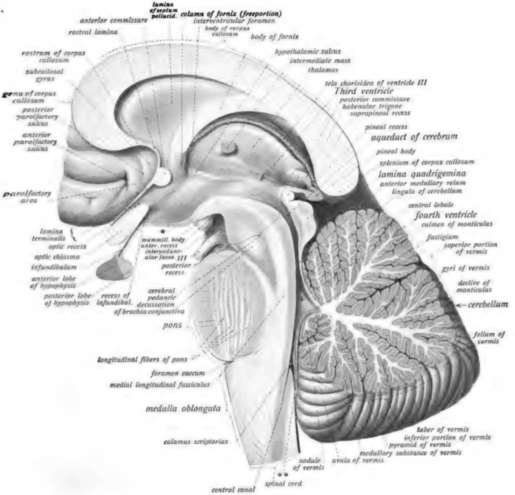
lamina of septum pellucid.
column of fornix (freeportion)
anterior commissure
interventricular foramen
rostral lamina
body of corpus callosum
body of fornix
rostrum of corpus callosum
hypothalamic sulcus
intermediate mass
thalamus
subcallosal gyrus
genu of corpus callosum
tela chorioidea of ventricle III
Third ventricle
posterior commissure
habenular trigone
suprapineal recess
posterior parolfactory sulcus
anterior parolfactory sulcus
pineal recess
aqueduct of cerebrum
pineal body
splenium of corpus callosum
lamina quadrigemina
anterior medullary velum
lingula of cerebellum
parolfactory area
central lobule
fourth ventricle
culmen of monticulus
lamina terminalis
*
mammill. body
anter. recess
interpeduncular fossa
III
optic recess
optic chiasma
infundibulum
posterior recess
fastigium
superior portion of vermis
gyri of vermis
anterior lobe of hypophysis
declive of monticulus
posterior lobe of hypophysis
recess of infundibul.
cerebral peduncle
decussation of brachia conjunctiva
cerebellum
pons
folium of vermis
longitudinal fibers of pons
foramen caecum
medial longitudinal fasciculus
medulla oblongata
tuber of vermis
inferior portion of vermis
pyramid of vermis
calamus scriptorius
medullary substance of vermis
nodule of vermis
uvula of vermis
**
spinal cord
central canal

Fig. 648.

and the posterior and lateral portion the broader end of the oval, its axis, therefore, running from an anteromedial to a posterolateral direction. Its upper surface is covered by a mass of white substance, the *stratum zonale*, and partly forms the floor of the central portion of the lateral ventricle; that is to say, the substance of the thalamus does not actually do this, but the lamina affixa (see page 150) which covers it. The anterior smaller end of the thalamus shows a variably developed thickening, the *anterior thalamic tubercle*, which, with the columns of the fornix, bounds the interventricular foramen, while the posterior broader part, which extends far beyond the posterior end of the third ventricle and forms the posterior portion of the thalamus, is called the *pulvinar* (posterior tubercle). The mesial surface forms the greater portion of the lateral wall of the third ventricle (see above) and is gray in color, and usually the medial surfaces of the two thalami are united by a soft, rather flattened mass of gray substance, the *intermediate mass* (middle or soft commissure); otherwise the two surfaces are separated by the narrow space of the third ventricle. At the line of transition of the upper wall of the thalamus into the medial, that is to say, along the upper border of the medial wall there is a distinct white band, which goes over into the habenular trigone posteriorly and is termed the medullary stria; to it is attached the epithelial chorioidal lamina in the form of the tænia thalami. The separation of the plane or slightly concave medial surface of thalamus from the hypothalamus is marked by the *hypothalamic sulcus* (sulcus of Monro) (see above), and similarly, the *stria terminalis* marks the boundary between the upper and lateral surfaces.

The remaining surfaces of the thalamus, namely, the lateral and inferior, and also the posterior portion of the medial, are not free, but are fused with the surrounding structures. The lateral surface and a part of the anterior portion is fused with the telencephalon by the fibers of the internal capsule, by which they are separated from the lenticular and caudate nuclei. The lower ventral surface comes into relation with the tegmentum of the brain stem and with the hypothalamus.

The thalamus contains, below the white surface, a number of nuclei which are not sharply outlined, but are separated from one another by *medullary laminæ* (internal). Three main nuclei are recognized: (1) The *anterior nucleus*, which lies in the anterior dorsal portion and corresponds to the anterior tubercle; (2) the *medial nucleus*, larger than the anterior one and lying near the medial surface of the middle and posterior portion of the thalamus; and (3) the *lateral nucleus*, generally the largest of the three, forming the lateral portion of the thalamus and extending from the region of the anterior nucleus to the pulvinar.

In addition to these three main nuclei, a few smaller ones also occur. The lateral surface of the lateral nucleus is covered by a white *external medullary lamina* and by a thin layer of gray substance, the *reticular stratum*, and by these it is separated from the internal capsule.

The *epithalamus* (Figs. 624, 637, 648, 650, and 660) is formed largely by the *pineal body* or *epiphysis*. This is a flattened, pear-shaped body which lies below the splenium of the corpus callosum in the transverse cerebral fissure. Its base is in front and is connected with the diencephalon through the habenula; the apex lies posteriorly and hangs freely down over the corpora quadrigemina of the mesencephalon, enclosed by pia mater and united to the tela chorioidea of the third ventricle.* The pineal body is connected with the diencephalon by the posterior com-

* In the anterior part of the upper surface of the pineal body the chorioidea is not firmly adherent, but is separated by the suprapineal recess (see page 156).

FIG. 649.—The roots of the optic nerves.

The brain stem has been removed by a transverse section through the superior colliculus. The cut surface is exposed to view.

FIG. 650.—The thalami, the epithalamus, the lamina quadrigemina, and the rhombencephalon, as seen from behind and above, after the removal of the larger portion of the cerebellum.

The corpus striatum, the thalami, and the third ventricle have been exposed by the removal of the corpus callosum, the fornix, and the tela chorioidea of the third ventricle. Upon the right side all of the cerebellum except the flocculus has been removed; upon the left side all but a portion of the medullary substance and of the hemisphere. The tela chorioidea of the fourth ventricle has been divided in the median line and reflected upon the right side.

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missure and also by the two *habenulæ*. These are white bands, which are the continuations of the *medullary striæ of the thalamus*, and unite at the upper border of the pineal recess to form a triangular plate, the *habenular trigone*,* whose floor is formed by a gray lamina, the *commissure of the habenulæ*, emerging from the substance of the pineal body, and forming the wall of the cavity of the pineal stalk, the *pineal recess*. Lime concretions known as *acervulus* or brain sand occur in the pineal body.

The *posterior commissure* (Figs. 624, 637, and 648) is a bundle of transverse fibers which projects into the third ventricle below the pineal body in such a manner as to bound the pineal recess inferiorly. Laterally, the commissure is lost in the walls of the thalamus.

The *metathalamus* (Figs. 650, 660, and 661) includes the two geniculate bodies which are white elevations and are known as the *medial* and the *lateral geniculate body*. The former is an elongated, round elevation behind the pulvinar of the thalamus; the latter is a fairly large thickening of the posterior lateral portion of the pulvinar itself. The two bodies are separated by a furrow and are in close connection with the optic tract and mesencephalon, and in each is a gray nucleus, the *nuclei of the medial* and *lateral geniculate bodies*.

From the geniculate bodies the *optic tract* arises (see page 154) by two roots, the *medial root* coming from the region of the medial geniculate body, and the broader *lateral root* not only from the lateral geniculate body, but also from the pulvinar of the thalamus. At their origins the optic tracts, especially the stronger lateral one, are very flat and broad, but as they curve around the brain stem they become narrower and thicker.

THE MAMMILLARY PORTION OF THE HYPOTHALAMUS.

The portion of the hypothalamus which lies behind the thalamus and belongs to the diencephalon, the *mammillary portion* (Figs. 624, 625, 635, 643, 647 to 650) in other words, receives its name from the two *corpora mammillaria* (candicantia), which form its main substance. These are two quite prominent, rounded or elongated eminences of the base of the brain, lying one on either side of the median line. They are separated from one another by a deep median fissure and are very conspicuous on account of their pure white color, which contrasts with the gray color of the tuber cinereum lying in front of them. Anteriorly and laterally, they are not very sharply bounded; the occasionally distinct connections which they may show with the lateral border of the tuber cinereum and the anterior perforated substance are called the *brachia of the mammillary bodies*. Each body contains two nuclei, the *nuclei of the mammillary bodies* (*medial* and *lateral*).

* In the habenular trigone there is also a small nucleus, the *habenular ganglion*.

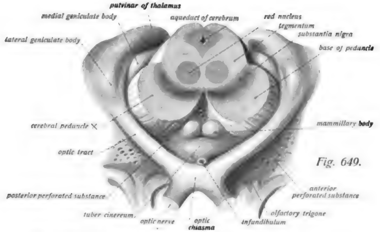


Fig. 649.

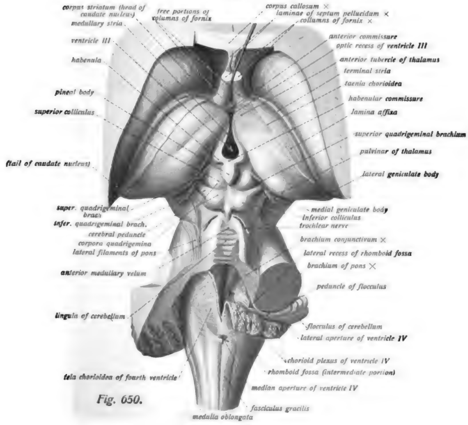


Fig. 650.

The mammillary portion of the hypothalamus also presents, in addition to the corpora mammillaria, a number of structures not visible on the external surface, but lying beneath the ependyma of the third ventricle. In the first place there is the *covered portion of the columns of the fornix* (see page 148), which extend down to the mammillary bodies, and from the bodies other fiber tracts pass off, which can be partly seen after removal of the covering ependyma. These are the *thalamo-mammillary fasciculus* or bundle of Vicq d'Azyr, which arises as a thick, almost cylindrical mass from the medial ganglion, and courses upward and medial, to terminate in the anterior nucleus of the thalamus; and the *pedunculo-mammillary fasciculus*, which arises from the lateral nucleus and passes to the cerebral peduncle, its *basilar portion* to the base of the peduncle, and its *tegmented portion* to the tegmentum. Furthermore, this part of the hypothalamus possesses a gray, almond-shaped nucleus lying below the thalamus and above the tegmentum of the cerebral peduncles, the nucleus of Luys or *hypothalamic nucleus*, while the remaining gray substance of the hypothalamus is known as the *gray portion of the hypothalamus*.

The Mesencephalon.

The *mesencephalon* (Figs. 624, 637, 647, and 652) is the smallest of the main divisions of the brain and undergoes the fewest changes during development (see page 125), its walls thickening very evenly, so that its cavity, the *cerebral* (*Sylvian*) *aqueduct*, is the narrowest part of the ventricular system of the brain and at the same time the only part whose walls are throughout composed of nerve tissue. Its dorsal portion is the *lamina quadrigemina*, the thicker ventral portion the *cerebral peduncles*, and the portion between these latter, the *interpeduncular fossa*. On the lateral surface are the *brachia quadrigemina*.

The *cerebral aqueduct* passes longitudinally through the mesencephalon lying above its axis. It begins at the opening of the aqueduct where, with its anterior upper end, it opens into the third ventricle, and it ends below and posteriorly in the fourth ventricle. Its axis is, therefore, oblique from anteriorly and above to posteriorly and inferiorly, and it is about 1½ cm. in length and varies considerably in diameter, being in the middle of its course almost heart-shaped and at the two ends more triangular, or even T-shaped. Enclosing the aqueduct is a mass of gray substance known as the *central gray stratum*, in whose ventral portion, in the region of the anterior corpora quadrigemina, is the *nucleus of the oculomotor nerve*, and further back, the *nucleus of the trochlear nerve*.

In addition to the *nucleus of the descending root of the trigeminus*, which has its origin in the mesencephalon, there are in the lateral portions of the central gray stratum a number of smaller nuclei, *e. g.*, the nucleus of the posterior commissure and that of the medial longitudinal bundle.

The Corpora Quadrigemina.

The *corpora quadrigemina* (Figs. 624, 637, 648 to 650, 660, and 661), which form the dorsal portion of the mesencephalon, are white on their superior surfaces and lie below the splenium of the corpus callosum and the pulvinares of the thalami, and form a plate, the *lamina quadrigemina*, upon whose anterior portion the pineal body rests. This lamina, as its name implies, is divided by a cruciform fissure into four eminences, of which the anterior larger but flatter pair is known as the *superior*, and the posterior smaller one as the *inferior colliculus*; the width of both colliculi is

about the same, but the anterior ones are longer than the posterior. From the fissure between the posterior pair the *frenulum of the anterior medullary velum* has its origin, but at its anterior edge the lamina becomes very thin and without any sharp line of demarcation passes over into the posterior commissure of the third ventricle.

The *brachia quadrigemina* (Figs. 650, 660, and 661) extend from the colliculi to the region of the metathalamus and also to the thalamus. From each of the superior colliculi, the *superior brachium quadrigeminum* passes laterally and penetrates the substance of the thalamus close to the medial geniculate body, while the more distinct and larger *inferior brachium* passes from the inferior colliculus along the lateral border of the superior colliculus toward the lateral geniculate body and posterior end of the thalamus, where it also is gradually lost in the substance of the thalamus.

The *cerebral peduncles* (Figs. 630, 642, 647 to 650, and 661), which form the ventral surface of the mesencephalon, are two diverging broad white bands lying almost concealed at the base of the brain and having an almost semicylindrical shape. They diverge at their exit from the anterior border of the pons, from which they are separated by a transverse fissure, and course anteriorly, laterally, and superiorly into the substance of the prosencephalon, thus forming the connection between cerebrum and brain stem. The optic tract passes below the anterior portion of the cerebral peduncle, and the hippocampal gyrus with its uncus covers it when the base of the brain is viewed from the side.

The medial boundary of the cerebral peduncle, *i. e.*, its line of separation from the interpeduncular fossa (see below), is formed by the *sulcus of the oculomotor nerve*, which runs parallel to the medial border of the peduncle. From it the roots of the third or oculomotor nerve emerge. Laterally the peduncle is separated from the lateral portion of the mesencephalon by the *lateral mesencephalic sulcus*.* The white surface of the peduncle exposed at the base of the brain is distinctly furrowed longitudinally.

In the angle between the two cerebral peduncles, which is bounded anteriorly by the corpora mammillaria, the inferior surface of the mesencephalon shows a deep triangular groove, the *interpeduncular fossa* (fossa of Tarini). Its floor is formed by the *posterior perforated substance*, which is gray at the base of the brain, but internally is largely composed of nerve fibers and thus is a whitish plate; it derives its name from being penetrated by numerous blood-vessels passing into the base of the brain. It extends from the anterior border of the pons to the corpora mammillaria, unites both peduncles, and by its upper anterior surface forms a portion of the floor of the third ventricle. It deepens toward the corpora mammillaria to form the *anterior recess*, and toward the pons to form the *posterior recess*.

The lateral surface of the mesencephalon, which lies between the lateral border of the lamina quadrigemina and the lateral mesencephalic sulcus, is formed in its upper portion of the brachia quadrigemina, and a little lower the tegmentum of the peduncle borders on this surface.

In contrast to the cerebrum, where, except in a few places (parts of the thalamus, hippocampus), one finds a quite regular distribution of the gray and white substances, the mesencephalon and also the whole brain stem shows a much more complicated arrangement, different

* These two sulci bound only the foot of the peduncle, which is all that is visible at the base of the brain. The tegmental portion of the peduncle lies above the lateral sulcus.

cross-sections of it showing a very varying distribution of the fiber tracts and gray nuclei, a condition depending largely upon the occurrence in these portions of the brain of the nuclei of the various cranial nerves on the one hand,* and on the other the paths which pass from the spinal cord to the brain and *vice versa*, to which still other gray nuclei and shorter paths are added (for instance, from the cerebellum). The relation of these parts can be best studied in cross-sections of the mesencephalon.

In such sections (Figs. 651 and 652) one sees dorsal to the cerebral aqueduct a section of the lamina quadrigemina, ventrally a section of the cerebral peduncles united, in the region of the tegmentum, above the interpeduncular fossa. The lamina shows white substance on its surface, the *stratum zonale*, but below this lies gray substance, which, in the region of the superior colliculi, is distributed rather diffusely, forming the *gray stratum of the superior colliculus*, while in the posterior colliculi it forms a more circumscribed nucleus, the *nucleus of the inferior colliculus.* Below the gray layer there is a mass of white fibers which separates the corpora quadrigemina from the central gray stratum of the cerebral aqueduct, this is the *deep white stratum.*

Much more complicated in structure is the larger portion of the mesencephalon, which lies below the cerebral aqueduct in the region of the cerebral peduncles. Here in the fresh brain a dark gray substance, almost semilunar in shape, the *substantia nigra*, can be seen. It separates † the base of the peduncle from the tegmentum, its concavity facing the latter. The *base of the peduncle*, lying below this mass, consists exclusively of medullated nerve fibers and is, therefore, of a pure white color and is semilunar in form in cross-sections. The masses of fibers form bundles, from which the furrows on the surface of the peduncle have their origin.

The *tegmentum* is the upper portion of the peduncle and lies above the substantia nigra. Superiorly it passes over without demarcation into the hypothalamic region and, below the aqueduct, the tegmenta of opposite sides are united. In this region the fiber tracts lying the furthest medially cross, forming the *decussation of the tegmenta.* The tegmentum itself consists of longitudinal, stronger and weaker fiber tracts, between which separate gray nuclei are situated. The largest of the latter is the *red nucleus* of the tegmentum, lying in the region of the anterior pair of corpora quadrigemina; it is circular in cross-section, is of a reddish color in the fresh brain, and lies close to the median plane, that is to say, in the medial half of the tegmentum. In addition to smaller nuclei, those of the trochlear and oculomotor nerves mentioned above and lying in the ventral portion of the central gray stratum, belong to the tegmentum. The root fibers of the latter partly traverse the substance of the red nucleus and have their exit at the sulcus of the oculomotor nerve. Lateral to these nuclei is the *reticular formation*, a mixture of small groups of ganglion cells and nerve fibers.

The fiber tracts of the tegmentum originate largely in the *brachia conjunctiva* (Fig. 652), which enter the posterior portion of the tegmentum. Here, behind the red nucleus, they form the *decussation of the brachia conjunctiva.* Furthermore, the *medial longitudinal fasciculus* (see page 184) appears as a special path in the white substance of the tegmentum, just below the central gray stratum (between it and the red nucleus) and close to the median line; it courses up

* With the exception of the optic and olfactory nerves, which differ in their relation from the other cerebral nerves.

† The substantia nigra, accordingly, extends between the sulcus of the oculomotor nerve and the lateral sulcus of the mesencephalon.

FIG. 651.—A cross-section of the mid-brain in the region of the superior colliculus. (Enlarged 4 times.)
FIG. 652.—A cross-section of the mid-brain in the region of the inferior colliculus. (Enlarged 4 times.)

The somewhat obliquely directed section in Fig. 652 has also included a portion of the superficial layer of the pons. The specimens have been prepared with Weigert's stain for the medullary sheaths. White matter (nerve fibers), dark, gray matter, clear.

from the medulla oblongata to the region of the hypothalamus, where it comes into relation with its nucleus mentioned above (page 159). The *lemniscus* also comes into consideration (see page 173). It lies lateral to the red nucleus and the decussation of the brachia conjunctiva and consists of the *lateral lemniscus*, a path of auditory fibers running to the geniculate body, and the *medial lemniscus*, going to the thalamus. The *descending root of the trigeminus*, which is connected with the nucleus mentioned above, can also be recognized as a special path in the dorsal portion of the tegmentum, lateral to the central gray stratum.

A small ganglion, known as the interpeduncular ganglion, lies on the floor of the similarly named fossa in the posterior portion of the posterior perforated substance.

THE RHOMBENCEPHALON.

THE RHOMBENCEPHALIC ISTHMUS.

The *rhombencephalic isthmus* (Figs. 648, 650, 660, and 661) is that portion of the rhombencephalon which forms the connection with the mesencephalon. It includes the *brachia conjunctiva*, the *trigone of the lemniscus*, and the *anterior medullary velum*. These parts form the dorsal and lateral portions of the isthmus, its ventral portion is formed by the most anterior portion of the floor of the rhomboidal fossa (see page 170), and its cavity is the portion of the fourth ventricle which follows immediately upon the cerebral aqueduct.

The *brachium conjunctivum* (Figs. 650, 652, 655 to 659, and 660 to 661) (of the cerebellum) unites on either side the cerebellum and mesencephalon, whence it has been spoken of as the cerebellar crus to the corpora quadrigemina or to the cerebrum. Each is an oval bundle, and the two diverge backward and downward toward the cerebellum almost touching one another at their anterior ends, where they sink beneath the inferior colliculi into the tegmentum of the cerebral peduncle, while posteriorly they enter the cerebellum through the transverse cerebellar fissure. Here the brachia come in close contact with the brachia pontis* and form by their inferior anterior surfaces a part of the roof of the fourth ventricle.

Between the two brachia conjunctiva a thin white lamina, the *anterior medullary velum*, is stretched. It is triangular in form, consists of nerve fibers, among others, of the fibers of the trochlear nerve, which decussate in it, and below and posteriorly it passes over into the medullary mass of the vermis of the cerebellum (see page 165). Its ventral (anterior, inferior) surface, together with the brachia conjunctiva, bounds the anterior part of the fourth ventricle above, its dorsal surface is largely fused with the lingula of the vermis which lies upon it, and anteriorly a narrow gray strip, known as the *frenulum of the anterior medullary velum* (valve of Vieussens),

* In the groove between the brachium conjunctivum and the brachium pontis, which appears as a sort of extension of the lateral mesencephalic sulcus, some distinct fiber tracts often make their appearance on the surface and are known as *lateral fila of the pons*. They pass along the anterior border of the pons.

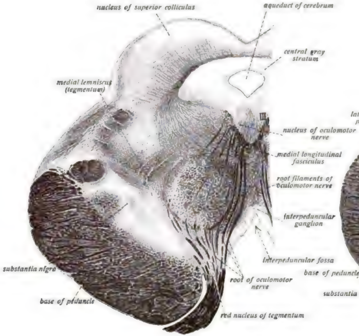


Fig. 651.

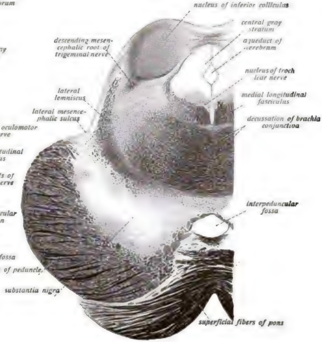


Fig. 652.

on either side of which the trochlear nerve has its origin, is continued forward to the quadrigeminal plate.

On the lateral surface of the rhombencephalic isthmus is a triangular area, the *trigone of the lemniscus* (Fig. 661), bounded laterally by the lateral mesencephalic sulcus, which separates it from the cerebral peduncle, medially by the lateral border of the upper portion of the brachium conjunctivum, and anteriorly by the inferior quadrigeminal brachium. It contains the lemniscus (see page 173), which is superficial in this part of its course and enters the mesencephalic tegmentum lateral to the brachum conjunctivum. It is distinguishable from the pure white brachium by its somewhat grayish color.

THE METENCEPHALON.

THE CEREBELLUM.

The *cerebellum* (Figs. 623, 624, 647, 648, and 653 to 658) is a specially marked portion of the whole brain, not only on account of the form of its surface but also because of its internal structure and comparatively isolated position. According to its development it belongs to the rhombencephalon and it consists of two *hemispheres*, the main lateral divisions, united by a median unpaired mass, the *vermis*.

The shape of the whole cerebellum is that of a transverse ellipsoid. Since it is united to the brain stem alone, and to this only by the three cerebellar peduncles (the brachia conjunctiva, brachia pontis, and the restiform bodies), its surfaces are everywhere free and for the most part convex. One main surface looks upward and at the same time backward and is moderately convex, but in such a manner that the vermis, which here passes over into the hemisphere without any line of demarcation, is the most prominent portion of the surface, resembling the ridge of a low roof. This surface of the cerebellum is separated from the adjacent portion of the cerebral hemispheres by the tentorium cerebelli (see page 189). The most anterior end of the vermis extends almost to the splenium of the corpus callosum and to the lamina quadrigemina.

The second main surface of the cerebellum looks downward and is largely visible on the uninjured base of the brain (see page 132); it rests upon the floor of the posterior cranial fossa. The hemispheres are more convex on this surface than on the upper one, and below the inferior vermis, which is sharply defined, there is a broad shallow invagination, the *vallecula* of the cerebellum, in which the medulla oblongata rests.

The two main surfaces of the cerebellum unite laterally and posteriorly in strongly convex, rounded borders. Anteriorly and posteriorly these borders present concavities, known as anterior and posterior notches; the latter passes over into the vallecula of the cerebellum. Since the upper and lower surfaces of the hemispheres meet posteriorly and laterally in a rounded-off acute angle, a posterior surface of the cerebellum cannot be distinguished. An anterior can be recognized, however, in whose middle portion the cerebellum is united with the brain stem, while its lateral portions are freely exposed at the base of the brain. The more median portion is transversely depressed between the cerebellar peduncles of either side and the anterior portion (nodule) of the inferior vermis, which forms the floor of the vallecula. This depression is known as the *transverse cerebellar fissure* and its inferior boundary is, in addition to the nodule of the vermis, the posterior medullary velum (see below).

FIG. 653.—The cerebellum viewed from above and behind.
FIG. 654.—The cerebellum viewed from below.
FIG. 655.—The anterior aspect of the cerebellum (divided from the brain-stem).
FIG. 656.—The inferior aspect of the cerebellum.

All of the brain-stem except the anterior portion of the pons has been removed by a curved incision passing through the pons. The tonsils and the contiguous portion of the biventral lobe have been removed to show the nidus avis.

The surface of the cerebellum is formed of gray substance which is divided off into separate small convolutions by the cerebellar sulci, which are more or less deeply penetrating, narrow, and generally parallel furrows. The surface of these cerebellar gyri is covered by the *cerebellar cortical substance*, which differs from that of the cerebrum in its microscopic structure.* The sulci and, accordingly, also the gyri have almost without exception a horizontal or at the most a slightly oblique course, and deeper sulci separate several small groups of gyri, called *cerebellar lobules*. The various lobules, which differ greatly in size, and the gyri also have as their central substance delicate *medullary laminæ* (see page 165). Gyri as well as sulci and even lobes pass without interruption from the hemisphere to the vermis, especially on the superior surface, nevertheless the lobules of the hemispheres have different names and also a different form from those of the vermis.

The Cerebellar Hemisphere.—Each cerebellar hemisphere (Figs. 653 to 658) is divided into a superior and inferior surface by the *horizontal sulcus*, which runs horizontally along the rounded lateral border. Larger sulci divide the superior surface into four lobules, which from before backward are:

1. The *vinculum of the lingula* (Fig. 655), consisting only of a few flat convolutions, which are the lateral prolongations of the lingula of the vermis, resting upon the anterior medullary velum, and extending toward the posterior portion of the brachium pontis.

2. The *ala of the central lobule* (Fig. 653), also consisting of but few gyri, which prolong the central lobe of the vermis laterally and lie along the anterior cerebellar notch.

3. The *quadrangular lobule* (Fig. 653), forming the main portion of the superior surface of the hemisphere, and, since it corresponds to the culmen and declive of the monticulus of the vermis, being divided by a deep fissure into an anterior and a posterior part.

4. The *superior semilunar lobule* (Fig. 653), which is a semilunar lobule pointed at the end, with a lateral side and a medial narrow one, and which is separated from the lower horizontal lobule by a similarly named sulcus.

The inferior cerebellar surface is also divided into four lobules, which follow the other series in this manner:

1. The *inferior semilunar lobule* (Fig. 654), lying below the horizontal sulcus and in contrast to the superior semilunar lobule, having a broad medial and narrow lateral border. It corresponds to the tubercle of the vermis and in its lateral portion has very narrow gyri.

2. The *lobus biventer* (Figs. 654 and 656) is much narrower on its mesial than on its lateral side, and consequently its gyri are only approximately parallel and laterally have no longer a horizontal direction. A deep curved sulcus divides it into a lateral and a medial portion. This lobe, which corresponds to the pyramid of the vermis, is always distinctly separated from the two neighboring ones.

* See the Sobotta-Huber *Histology*, Lehmann's *Medical Hand-Atlases*, Vol. XXVI.

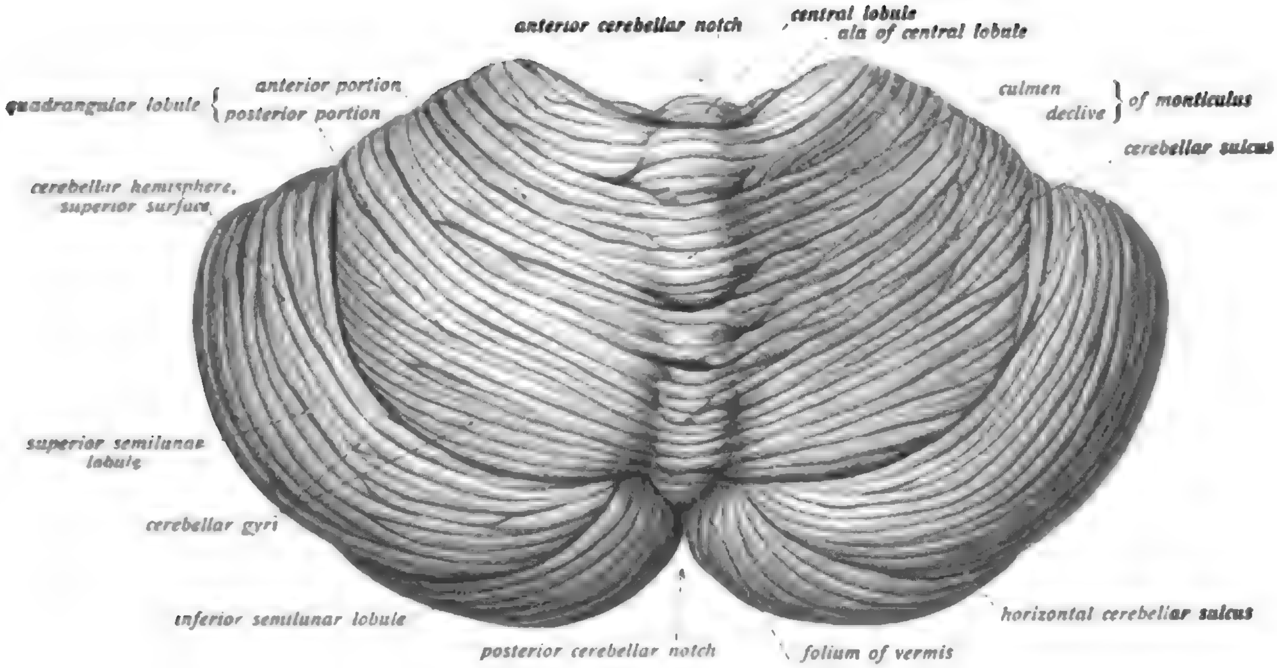


Fig. 653.

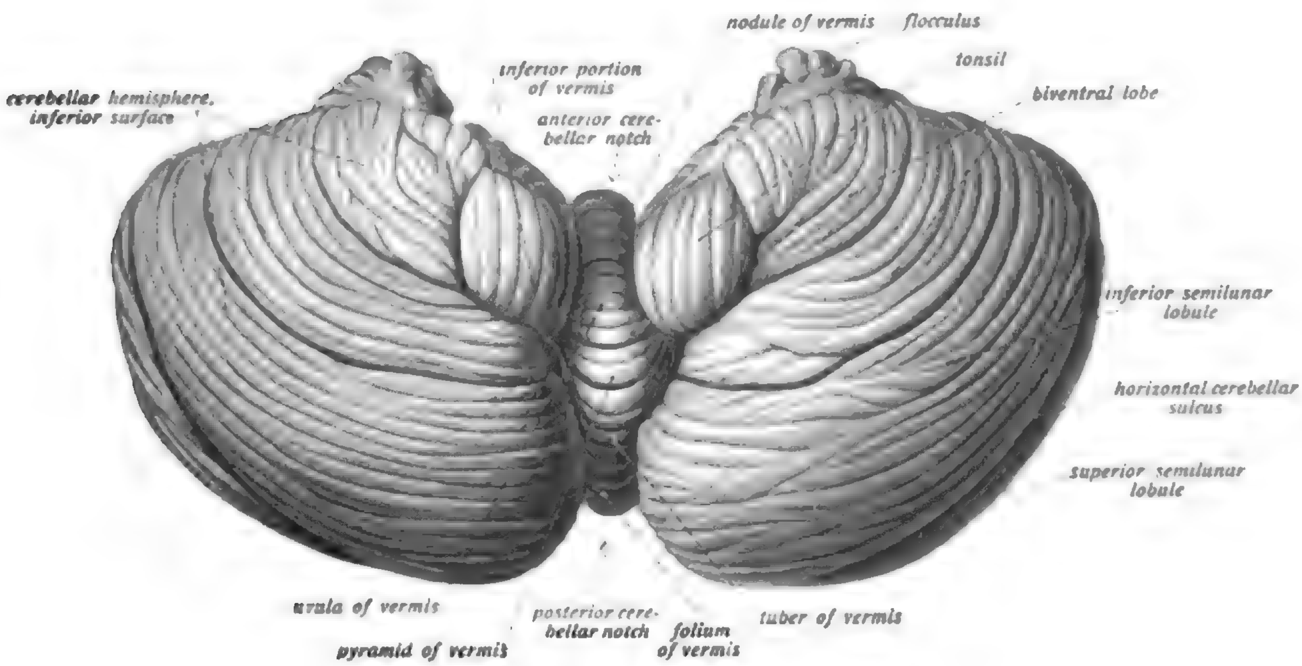


Fig. 654.

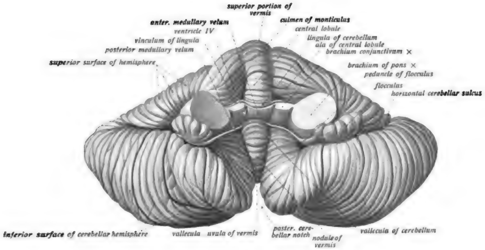


Fig. 655.

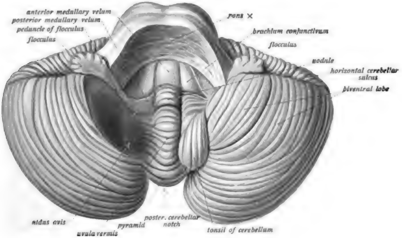


Fig. 656.

3. The *tonsil* (Figs. 654 and 656) is an almost oval, very prominent lobule, which lies between the preceding one and the vallecula. Its fissures and convolutions are the only ones of the cerebellum which run almost vertically. It corresponds to the uvula of the vermis.

4. The *flocculus** (Figs. 654 to 656) is a small peculiar stalked lobe which lies at the posterior border of the brachium pontis in front of the lobus biventer, in the prolongation of the horizontal sulcus which separates this from the quadrangular lobule. It consists of only a few gyri, separated by notched sulci, and is connected with its corresponding lobule in the vermis, the nodule, only indirectly by means of a medullary band, the *peduncle of the flocculus*, which posteriorly passes over into a thin lamina, the *posterior medullary velum*. This, with the peduncles of the flocculus, lies behind the brachium pontis and restiform body, between these and the anterior border of the tonsil. It bounds a groove-like depression on the inferior surface of the cerebellum, in which the tonsilla rests and which is called the *nidus avis*.†

The interior of the hemisphere (Fig. 658) consists of a white medullary mass, the *medullary body*, which is most compact in the center of the hemisphere and penetrates in the form of the various branched medullary laminæ into the lobules and the individual gyri. In this manner a structure, called the *arbor vitæ*, is formed, which is shown by a cross-section at right angles to the convolutions, at an angle of 45 degrees with the median plane. The medullary mass of the hemisphere contains a number of gray nuclei or ganglia, of which the most important is the *dentate nucleus* (Figs. 657 and 658). It is a much-folded thin plate of gray substance which is interrupted medially by the medullary mass. The place of interruption is known as the *hilus*, and a layer of nerve fibers which surround the gray substance of the nucleus is the *capsule*. Its greatest length is in the direction of the prolongation of the brachia conjunctiva.

In close relation with the dentate nucleus are the remaining smaller nuclei of the cerebellum (Fig. 658), which also lie in the medullary mass, but extend partly into the region of the vermis.

Immediately medial to the dentate nucleus is the elongated *emboliform nucleus;* on the medial surface of this is the *nucleus globosus*, consisting of two or three parts; while the *nucleus fastigii* is in the upper portion of the medullary body of the vermis close to the median plane and just above the fourth ventricle.

The three cerebellar peduncles radiate from the medullary mass of the cerebellum; they contain the fiber tracts and connect the cerebellum with the brain stem. The largest of the three is the middle one, the *brachium of the pons* (Figs. 650, 655, 660, and 668). To it there is added from below the *restiform body*, which comes from the medulla oblongata, while the flat *brachium conjunctivum* lies superiorly and medially. All three enter the cerebellum through the transverse cerebellar fissure.

The Vermis.—The *vermis* (Figs. 648 and 653 to 656) is the narrow middle connection between the two cerebellar hemispheres. The portion of it which forms part of the superior cerebellar surface projects above the level of the hemispheres and is called the *superior vermis*, while the lower portion, which lies in the *vallecula* forming the floor of that groove, is the *inferior vermis*, and is much more distinctly separated from the hemispheres than the superior vermis, from which it is separated by the transverse cerebellar fissure. In the region of the posterior

* In addition to the actual flocculus, secondary flocculi sometimes occur along the border of the brachium pontis.

† The nidus avis does not appear until the tonsilla is removed, and is, therefore, an artificial product.

FIG. 657.—The boundaries of the fourth ventricle exposed by a partial removal of the cerebellum.

The vermis of the cerebellum, excepting the lingula and the nodule, has been cut away, and the posterior halves of the hemispheres removed by an almost vertical section. The tonsil and the biventral lobe have also been removed from the left hemisphere to expose the posterior medullary velum.

FIG. 658.—A cross-section of the cerebellum in the direction of the brachia conjunctiva.

cerebellar notch, however, it passes over gradually into the superior vermis, so that the surface of the whole vermis represents about three-fourths of a circle and is marked with distinct transverse fissures.

Like the hemisphere, the vermis is divided into eight subdivisions, there being four lobules in the superior and four in the inferior vermis. Those of the superior vermis are: 1. The ***lingula*** (Fig. 655), the smallest lobule, consisting of four to five narrow, flat gyri which lie upon the dorsal surface of the anterior medullary velum. It corresponds to the vinculum of the lingula on the hemispheres.

2. The ***central lobule*** (Fig. 658) is also small, although it is larger than the lingula and has in its interior a medullary lamina covered with gray cortex on both sides. It is situated in the anterior cerebellar sulcus behind the corpora quadrigemina, covers in the lingula, and passes over into the ala of the central lobule of the hemisphere.

3. The ***monticulus*** (Fig. 653), the largest portion of the superior vermis and, in fact, of the whole vermis, forms the ridge-like projection of the surface of the cerebellum and is steeply inclined forward toward the central lobe, but a little less so posteriorly toward the folium of the vermis. Its anterior portion, which is the most prominent, is called the ***culmen***, and its posterior portion the ***declive***. It corresponds to the quadrangular lobe of the hemisphere.

4. The ***folium*** (Figs. 653 and 654) is situated in the posterior cerebellar sulcus and is a low fold, divided into but few convolutions, which unites the superior semilunar lobules.

The inferior vermis is divided into:

1. The ***tuber*** (Fig. 654), which also lies partly in the region of the posterior cerebellar sulcus and unites the inferior semilunar lobules of the hemisphere.

2. The ***pyramid*** (Fig. 656) is much broader at its posterior than at its anterior end and thus obtains its name. It corresponds to the lobus biventer of the hemisphere.

3. The ***uvula*** (Figs. 655 and 656) is elongated and lies between the two tonsils of the hemispheres.

4. The ***nodule*** (Figs. 655 and 656) is the most anterior lobule of the vermis, bordering directly upon the transverse cerebral fissure. It is round and corresponds to the flocculus, with which it is connected by the peduncle of the flocculus.

The lobules of the vermis and the hemisphere are related to one another in the following manner:

	Hemisphere.	*Vermis.*	
Superior surface.	1. Vinculum of the lingula.	1. Lingula.	Superior vermis.
	2. Ala of central lobule.	2. Central lobule.	
	3. Quadrangular lobule.	3. Monticulus.	
	4. Superior semilunar lobule.	4. Folium.	
Inferior surface.	1. Inferior semilunar lobule.	1. Tuber.	Inferior vermis.
	2. Lobus biventer.	2. Pyramid.	
	3. Tonsil.	3. Uvula.	
	4. Flocculus.	4. Nodule.	

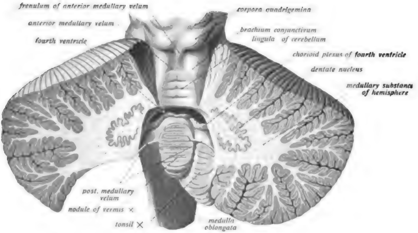


Fig. 657.

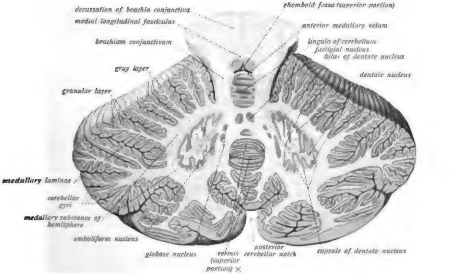


Fig. 658.

The medullary body of the vermis (Figs. 624 and 648) is much thinner than that of the hemisphere, and passes over into the anterior medullary velum, upon which the lingula of the vermis lies, without any line of demarcation. The medullary laminæ which it sends out are also much more delicate than those of the hemisphere, so that upon median cross-section of the vermis one gets the beautiful figure of the *arbor vitæ of the vermis.* The medullary body of the vermis with the anterior medullary velum forms a part of the roof of the fourth ventricle (see page 171).

The Pons.

The *pons* (Figs. 623, 624, 642, 647, 648, and 661) is a broad white mass, lying at the base of the brain and separated anteriorly from the cerebral peduncles by a distinct groove and posteriorly also from the medulla oblongata. Laterally it is connected to the cerebellum by the brachia pontis and anteriorly and posteriorly it is continuous with the cerebral peduncles and the medulla oblongata. Its surface, which forms part of the base of the brain, is decidedly convex in the transverse direction, but in the middle line has a shallow anteroposterior groove called the *basilar sulcus,* which lodges the basilar artery.

In shape the ventral surface is quadrangular and it is marked by distinct transverse lines and fissures corresponding to the course of the superficial pons fibers. An oblique fiber tract which runs from an anterior medial to a posterior lateral direction toward the brachium pontis, is usually quite distinct and is known as the *oblique fasciculus* This surface lies upon the clivus of the posterior cranial fossa.

The pons is connected with the cerebellum on either side by the large brachia pontis, while its dorsal surface forms the floor of the fourth ventricle and really represents the intermediate portion of the rhomboidal fossa (see below). This dorsal surface is gray, while the ventral and lateral surfaces are white. The portion of the pons taking part in the formation of the rhomboidal fossa is known as the *dorsal portion* and differs considerably in its entire structure (see page 175) from the ventral or *basilar portion.*

The *brachium pontis* is a thick, round mass of fibers which passes from the lateral part of the pons and, thinning a little at first and then thickening again, enters the medullary mass of the cerebellar hemisphere near the brachium conjunctivum. From its base the largest of all the cranial nerves, the *trigeminus,* has its origin just in front of the oblique fasciculus. Where it enters the cerebellum it is covered by the lobules of the latter above, behind by the quadrangular lobe, and below by the lobus biventer, and especially by the flocculus. Between its posterior border and the anterior end of the olive (see below) the acoustic and facial nerves have their exit.

The Medulla Oblongata. (Myelencephalon.)

The *medulla oblongata* (Figs. 623, 624, 642, 647, 650, 660, and 661), the direct prolongation of the spinal cord, has the shape of a cylinder somewhat enlarged at its anterior end. At its lower end it becomes directly continuous with the spinal cord, while its upper end passes into the pons, from which it is separated on the ventral surface by the groove mentioned above.

So far as its external form is concerned, the medulla oblongata greatly resembles the spinal cord, especially on its ventral surface and in its lower half. The *anterior median fissure* of the

* For the lateral fila of the pons, see page 162.

FIG. 660.—The quadrigeminal lamina and the rhomboid fossa as viewed from behind.
The cerebellum and the pineal body have been removed; the posterior extremity of the thalamus may be seen.
FIG. 661.—The same preparation viewed from the left and somewhat from behind.

cord is prolonged throughout the entire length of the medulla and forms at its upper blind end, together with the transverse groove between the medulla and pons, a depression known as the *foramen cæcum.* At the boundary between the spinal cord and the medulla the longitudinal fissure is interrupted by the crossing of the pyramidal tract of the cord, this bundle passing from the lateral funiculus of one side obliquely through the longitudinal fissure to the anterior funiculus

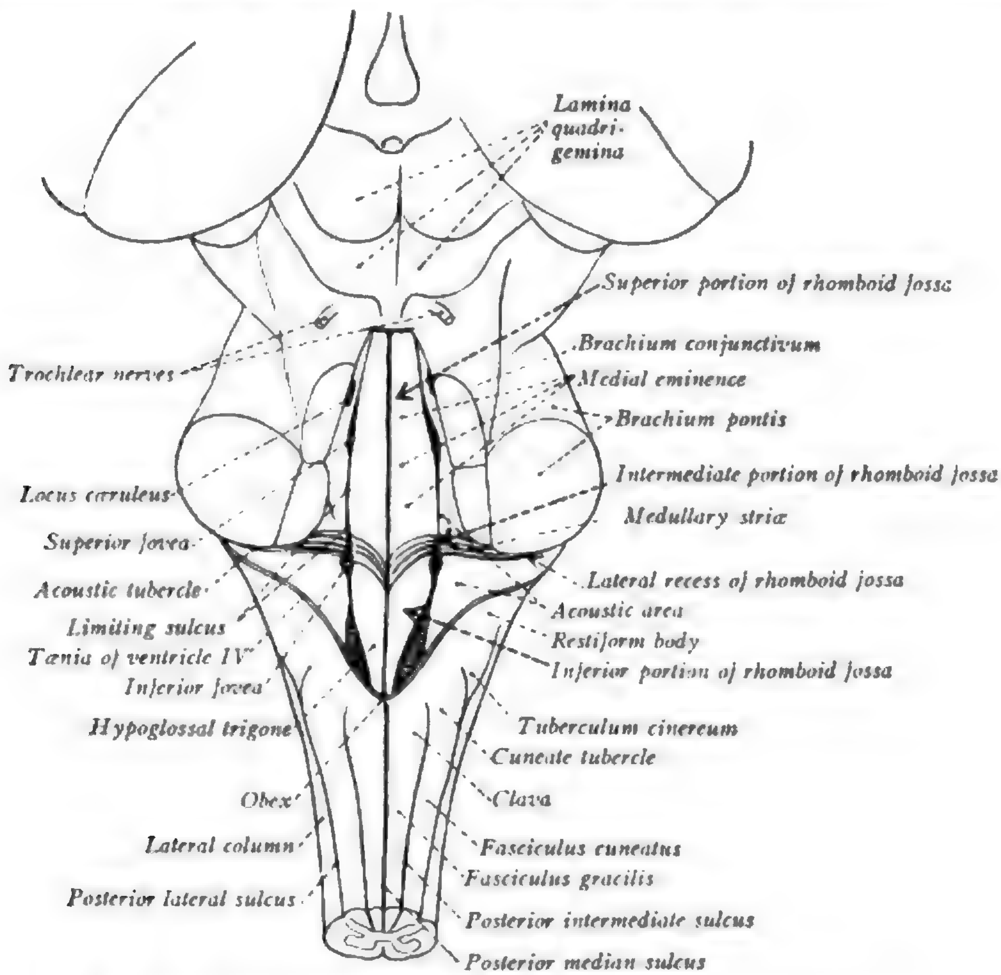


FIG. 659.—Explanation and additions to Fig. 660. The ala cinerea is shaded.

of the other side. This crossing is termed the *pyramidal decussation,** and the anterior funiculi of the medulla, now containing all the pyramidal fibers and lying as continuations of the anterior funiculi † of the spinal cord, next to the median fissure, are called the *pyramids.* Laterally these

* The fibers of the anterior pyramidal fasciculus (see page 110) had the same position in the cord.

† In reality, the pyramids are not the real continuation of the anterior funiculi. They merely push the anterior fasciculus proprius (see page 110) laterally and occupy the space near the median plane.

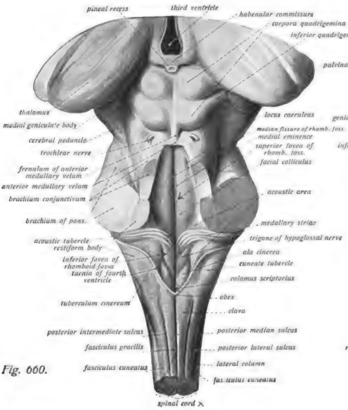


Fig. 660.

Fig. 661.

are bounded by the prolongations of the anterior lateral sulci of the cord, from which, in the upper portion of the medulla, the twelfth or *hypoglossal nerves* have their origin by a number of root fibers, while in the lower portion of the medulla the root fibers of the first cervical nerves emerge.*

In the prolongation of the lateral funiculi of the cord in the upper portion of the medulla there is near the pyramid and separated from it by the *anterior lateral sulcus* an elongated elliptical prominence, the *olive*, which is of a white color, as is, indeed, the whole ventral surface of the medulla oblongata. A considerable portion of the lateral funiculus, however, passes lateral to the olive and ascends toward the pons, and there are, even externally, evidences of extensive changes in this lateral funiculus compared with that of the cord, the remains of the enlarged posterior horn of the cord, for instance, coming to lie just below the surface in the vicinity of the fasciculus and forming the *tuberculum cinereum.* The root fibers of the eleventh or *accessory nerve* have their exit from the lateral funiculus along the whole length of the medulla oblongata, and in its upper part, lateral to the olive, the fibers of the *glossopharyngeal* and *vagus nerves* make their appearance, and at the upper border of the olive may be seen those of the *facial* and *acoustic nerves.*

Just as the anterior funiculi of the cord pass insensibly into those of the medulla, so also is it with the posterior funiculi. Each of these presents two very differently shaped portions. In its lower portion each is in every respect similar to the cord, but its upper portion forms a part of the floor of the fourth ventricle and the *inferior portion of the rhomboidal fossa.* Consequently, the *posterior median sulcus* of the cord is not continued throughout the whole length of the medulla, but only through its lower half, its upper being cut off by a transverse triangular medullary fold, the *obex.* The *posterior intermediate sulcus,* which is quite distinct in the cervical portion of the cord, passes up a little higher, and the fasciculus gracilis, lying between it and the posterior median sulcus, forms at its end a club-shaped swelling, the *clava.* The lateral portion of the posterior funiculus behaves similarly at its passage into the medulla, the fasciculus cuneatus forming somewhat lateral to and above the clava the *tuberculum cuneatum,* which is separated from the tuberculum cinereum (mentioned above) by the posterior lateral sulcus.

Above the clavæ and medial to the cuneate tubercles is the inferior portion of the rhomboidal fossa (see page 170), and on either side of it a flattened bundle formed from portions of the posterior funiculi and also from prolongations of the lateral funiculi of the cord, especially of the direct cerebellar fasciculus (see page 116). It curves upward to the cerebellum, lying along the posterior inferior border of the brachium pontis, and with this enters the transverse cerebellar fissure; it is known as the *restiform body.*

The dorsal surface of the medulla oblongata extends in the floor of the rhomboidal fossa to about the transverse striæ (see below), but in this region there is no sharp line between medulla and pons, so that in the description of the rhomboidal fossa (page 170) both portions will be considered together. Just as there is a gradual change in external form from the spinal cord to the medulla oblongata, so too there is a gradual rearrangement of the separate parts of the cord, both the gray and the white substance being concerned in the change, so that below, even in its internal structure, the medulla oblongata resembles the cord, while its upper part, on account of

* Since the roots of these nerves arise above the pyramidal decussation, the latter cannot be considered as a sharp boundary between the cerebrum and the spinal cord.

the appearance of gray nuclei and the rearrangement of the white fiber tracts, presents quite a different appearance. The more minute relations of the parts will be discussed later when the structure of the pons is considered.

The Fourth Ventricle.—The fourth ventricle (Figs. 624, 648, 650, 659, and 660) is a low flat space, which communicates superiorly with the cerebral aqueduct, and inferiorly directly with the central canal of the spinal cord. The middle and widest portion of the cavity belongs to the metencephalon, while the upper pointed end lies in the region of the rhombencephalic isthmus, and the lower end, also pointed, belongs to the medulla oblongata. It presents for examination a floor formed by the *rhomboidal fossa*, and a roof known as the *tegmen of the fourth ventricle.*

The shape of this flat ventricle corresponds largely to the rhomboidal fossa, presenting at the middle of its length its greatest width, the *lateral recess of the fourth ventricle*, which corresponds to the lateral recess of the rhomboidal fossa and extends along the peduncle of the flocculus to the medial and posterior border of the flocculus, and is connected with the subarachnoid space by the *lateral aperture of the fourth ventricle*, which latter extends along the root fibers of the glossopharyngeal nerve. Here the chorioid plexus of the fourth ventricle makes its appearance at the base of the brain. At about its middle the ventricle also has its greatest depth, due to an out-pouching directed toward the medullary body of the vermis and known as the *fastigium* (page 171).

The Rhomboidal Fossa.—The rhomboidal fossa (Figs. 660 and 661) is a flat rhomboidal groove-like indentation, which is seen separating the cerebellum from the brain stem, lying upon the surfaces of the rhombencephalic isthmus, the pons, and the medulla oblongata, which form the floor of the fourth ventricle. The upper and lower extremities of the fossa are acute angles and the lateral ones are obtuse, so that its greatest width is at its middle. The upper pointed end communicates with the cerebral aqueduct, while the lower one is continued as a pen-shaped figure, the *calamus scriptorius*, into the central canal of the cord. Its boundaries in the region of the calamus scriptorius are the *obex* (see page 169), the upper ends of the clavæ, and laterally the restiform bodies, and in its upper part its boundaries are the brachia conjunctiva. Three portions which are continuous with one another without any definite lines of demarcation may be distinguished; the broadest middle portion is termed the *intermediate portion*, the upper, the *superior*, and the lower, the *inferior portion.* The middle part presents a *lateral recess* between the restiform body, which curves upward toward the cerebellum, and the lower border of the brachium pontis.

Throughout its whole length, from the calamus scriptorius to the opening into the cerebral aqueduct, there extends the *posterior median fissure*, and parallel to this is a second less prominent (paired) lateral groove, the *limiting sulcus.** Together with the median fissure, this bounds an elongated eminence, the *medial eminence*, in the upper and middle portions of the fossa, while in the inferior portion, the prolongation of this, the *hypoglossal trigone*, is separated by the limiting sulcus from the ala cinerea (see below). The limiting sulcus forms in both the upper and lower portions of the fossa a broad depression, the *superior* and *inferior foveæ*, the former lying above, and the latter below the *medullary striæ (acoustic)*. These appear often as very distinct horizontal

* The limiting sulcus, like the lateral mesencephalic sulcus, is the remains of the embryonic limiting sulcus which separates the ventral and dorsal zones of the medullary canal.

white stripes, but are very variable in their development, and they pass across the greatest breadth of the intermediate part. They are quite narrow where they emerge from the median fissure, but diverge as they pass over the medial eminence toward the lateral recess, where they are lost; a few may often be seen to pass obliquely upward or downward.

Above the medullary striæ the medial eminence is thickened to form the flat *facial colliculus*, which lies medial to the superior fovea and is formed by the internal genu of the facial nerve. The lateral part of the fossa crossed by the medullary striæ is known as the *acoustic area*, because in this situation the eighth nerve has its origin or rather termination. Laterally, in the region of the lateral recess, it forms the *acoustic tubercle*, and above the superior fovea, in the lateral portion of the superior part of the fossa, is a narrow, elongated band, which has a bluish color in the fresh brain, and is termed the *locus cæruleus*.

In the inferior portion of the fossa, adjoining the hypoglossal trigone, and separated from it by the limiting sulcus, is a long triangular area, the *ala cinerea*, which is distinguished from the medial eminence by its deeper gray color. It corresponds to the vagoglossopharyngeal nucleus and extends upward to the inferior fovea.

The Tegmen of the Fourth Ventricle.—The *tegmen of the fourth ventricle* (Figs. 648, 650, and 657) is, for the most part, purely epithelial in character. An *epithelial chorioidal lamina* closes off the upper part of the cavity posteriorly as far down as the portion which belongs to the rhombencephalic isthmus. Here the brachia conjunctiva, with the anterior medullary velum lying between them, form a portion of the roof of the cavity, consisting of nerve tissue, but below this the roof is made up of the *tela chorioidea*, which resembles the similarly named structure of the third ventricle. It is a double fold of pia mater, which dips in between the cerebellum and fourth ventricle, covering, on the one hand, the nodulus and uvula of the cerebellum, and on the other, serving as a support for the epithelial chorioidal lamina. The latter projects into the ventricle as a chorioidal plexus, and consists of weaker, villus-like medial portions and a much stronger lateral one, passing along the peduncle of the flocculus and reaching to the lateral aperture, through which it emerges (see page 170).

The epithelial chorioidal lamina is attached along the restiform bodies to a narrow medullary edge, the *tænia of the fourth ventricle*, which extends along the side of the inferior portion of the rhomboidal fossa and also to the obex, lying between the upper parts of the two clavæ, the tæniæ passing over into this latter; it is also attached to the free borders of the *posterior medullary velum*. This, in contrast to the anterior velum, is a paired formation which is attached on either side of the peduncle of the flocculus. Its posterior superior border unites on either side with the posterior border of the anterior medullary velum and with this passes over into the medullary substance of the cerebellar vermis. The angle caused by this union is the *fastigium*, and in this region the fourth ventricle projects upward into the medullary substance of the vermis. On the other hand, the epithelial lamina is attached to the inferior border of the posterior velum, so that together they form the posterior wall of the fourth ventricle. In the middle line, just above the calamus scriptorius, there is a round aperture in the tegmen, the *medial aperture* (*foramen of Magendie**), through which the ventricle communicates with the subarachnoid cavity.

* The existence of this aperture has been denied. It is in any event a secondary formation and does not exist in the embryonic brain.

FIG. 662.—A cross-section of the medulla oblongata near the middle of the decussation of the pyramids. (Enlarged 7 times.)

FIG. 663.—A cross-section of the lower portion of the medulla oblongata at the level of the upper extremity of the decussation of the pyramids. (Enlarged 7 times.)

FIG. 664.—A cross-section through the lower portion of the medulla oblongata in the region of the decussation of the lemniscus. (Enlarged 7 times.)

White matter, dark; gray matter, clear.

FIG. 665.—A cross-section through the middle portion of the medulla oblongata in the region of the calamus scriptorius. (Enlarged 7 times.)

THE NUCLEI AND THE DISTRIBUTION OF THE MAIN FIBER-TRACTS IN THE PONS AND MEDULLA OBLONGATA.

The somewhat complicated distribution of the gray and white substance in the medulla and pons can be best understood by the study of a number of cross-sections from the spinal cord upward (Figs. 662 to 669). The most noticeable change in the transition from the cord into the medulla is that produced by the pyramidal decussation (Fig. 662). The fibers of the lateral pyramidal fasciculi deviate from their longitudinal course and take a transverse or oblique direction, traversing the gray substance in such a manner as to constrict the anterior from the posterior column, and decussate in front of the commissure with fibers of the other side, filling up the anterior median fissure. At the level of the upper end of the decussation nuclei may be seen in the clava and the cuneate tubercle, the *nucleus of the fasciculus gracilis* and *of the fasciculus cuneatus*. As in the cervical region of the cord, so in that of the lateral funiculus, the root fibers of the spinal accessory nerve, which arise from the lateral part of the anterior gray column, have their exit.

Just above the decussation a change in the structure of the gray substance takes place (Fig. 663). The posterior column is constricted off by fiber tracts which traverse the anterior column and the neck of the posterior one, forming the *reticular formation*, and becomes situated near the surface of the lateral funiculus, where it forms the *tuberculum cinereum* (see page 169). Its ganglion cells represent here, as in the succeeding cervical part of the cord, the *nucleus of the spinal tract of the trigeminus*, one of the sensory nuclei of that nerve. The neighboring bundles constitute the *spinal tract* of the nerve itself.

The anterior column of the cord above the decussation becomes gradually lost in the reticular formation, so that in addition to the *central gray stratum* surrounding the central canal the only larger masses of gray substance which persist are those of the tuberculum cinereum, the two nuclei of the posterior fasciculus, and a small lateral nucleus which makes its appearance in the lateral funiculi. The compact mass of fibers resulting from the decussation forms the *pyramid* lying next to the anterior median fissure, and it produces in the first place a lateral transference of the anterior fasciculus proprius and, secondly, causes a pronounced thickening of the ventral portion of the medulla oblongata, so that in transverse section the central canal is found in its dorsal half. Just above the level of the decussation of the pyramids masses of fibers occur, which also decussate, forming the *decussation of the lemniscus*. The fibers which enter into its formation are known as the *internal arcuate fibers*, in contrast to the delicate bundles of *external arcuate fibers* which run transversely over the surface of the medulla. The former (Fig. 664)

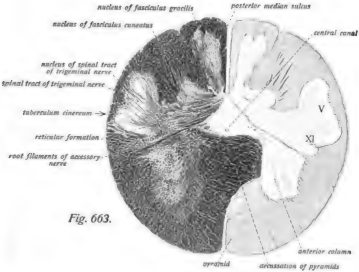


Fig. 663.

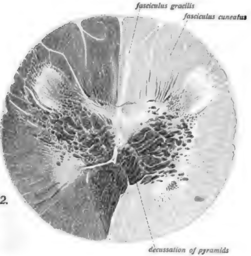


Fig 662.

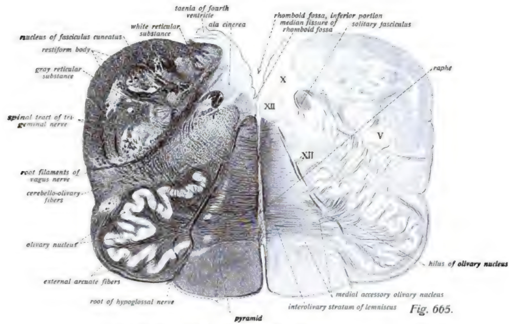


Fig. 665.

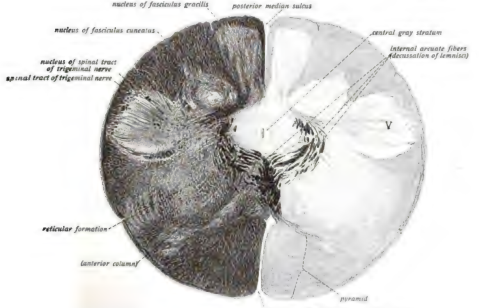


Fig. 664.

arise from the nuclei of the posterior columns and are indirect prolongations of the sensory fibers of the cord which form the posterior funiculus* (see page 118); from the nuclei of Goll and Burdach they curve around the central gray stratum to the median line, where they decussate at the bottom of the anterior median fissure, and since they represent the main portion of the path known as the ***medial lemniscus***, their decussation is termed the decussation of the lemniscus.

In the region of the calamus scriptorius (Fig. 665) the appearance of the cross-section of the medulla is altered, not only externally by the central canal opening into the fourth ventricle but also by other more extensive modifications. The gray figure seen in the cord can now be hardly recognized; the central gray stratum of the central canal has become the gray substance of the rhomboidal fossa, the remains of the posterior column may be recognized in the nucleus of the spinal tract of the trigeminal nerve as in the lower parts of the medulla, but the most noticeable alteration is the appearance of the ***olivary nucleus***, which appears below the calamus scriptorius just above the decussation of the lemniscus. It lies in the enlargement of the ventral surface of the medulla oblongata, known as the olive, not reaching the surface of this, however, but being separated from it by white fibers, especially by the ***external arcuate fibers***. The olivary nucleus (inferior) is a much-folded gray band curved so as to form a sac-like structure having an opening medially and posteriorly, the ***hilus***, and enclosing masses of fibers having various courses. Beside the main nucleus, accessory nuclei occur; separated from it medially by the root fibers of the hypoglossal nerve is the ***medial accessory olivary nucleus***, and, a little further dorsally is the ***lateral accessory olivary nucleus***. In the gray substance in the floor of the rhomboidal fossa are nuclei of several cerebral nerves. That of the hypoglossal nerve lies close to the median fissure of the fossa in the region of the medial eminence (see page 170), and corresponds to the trigone of the hypoglossal nerve of the rhomboidal fossa. The root fibers after leaving the nucleus pass obliquely, laterally, and ventrally to make their exit between the pyramid and olive. Lateral to the nucleus of the hypoglossal nerve is the ***nucleus of the ala cinerea***, the sensory nucleus of the glossopharyngeal and vagus nerves, whose root fibers pass from here through the substance of the lateral funiculus. Ventral and lateral to the nucleus of the ala cinerea a small, isolated tract, circular in cross-section, the ***solitary tract***, becomes especially prominent, and with it also an adjacent nucleus, the ***nucleus of the solitary tract***, both of which belong to the glossopharyngeal nerve.†

In the median plane the cross-section of the medulla shows a sharp separation of the two halves by means of the ***raphe*** of the medulla oblongata, in which a delicate decussation of fibers of both sides occurs, representing a continuation of the decussation of the lemniscus. Lateral to the raphe is a region extending to the root fibers of the hypoglossal nerve, in which several groups of ganglia lie between fiber tracts having various courses, and among which the internal arcuate fibers may be recognized passing to their decussation in the raphe. Since the fibers are in excess of the gray substance in this region, it has here a whitish appearance and is known as

* [The external arcuate fibers also arise from the nuclei of the posterior funiculus and, after decussating, pass ventrally to emerge at the anterior median fissure, whence they pass laterally over the surface of the medulla to join the restiform bodies and so reach the cerebellum.—ED.]

† [The solitary fasciculus is a downward prolongation of the entering fibers of the glossopharyngeal (and vagus) nerve and its nucleus is the nucleus of termination for these fibers, the two structures having the same relation to the nerve as the spinal tract and nucleus of the tuberculum cinereum have to the trigeminus.—ED.]

FIG. 666.—A cross-section through the middle portion of the medulla oblongata. (The middle of the olivary region.) (Enlarged 7 times.)

White matter, dark; gray matter, clear.

FIG. 667.—A cross-section through the upper portion of the medulla oblongata. (Intermediate portion of the rhomboid fossa.) (Enlarged 7 times.)

FIG. 668.—A cross-section through the lower portion of the pons at the level of the abducens nucleus. (Enlarged five times.)

The first portion of the root of the facial nerve is not visible; the second portion has been cut longitudinally and the genu obliquely. At one side may be seen the brachium of the pons, which has been divided from the cerebellum. Preparation as in Figs. 651 and 652.

FIG. 669.—A cross-section through the middle portion of the pons and of the rhombencephalic isthmus. (Enlarged five times.)

White matter, dark; gray matter, clear, as in Fig. 668.

the *white reticular substance*, in contrast to the *gray reticular substance* which is lateral to the root of the hypoglossal nerve and dorsal to the olive. The part of the white reticular substance which lies between the two olives is the *interolivary stratum of the lemniscus* and is largely formed by the internal arcuate fibers. On the ventral side of the medulla, ventral to the white reticular substance and lateral to the olives, are the *pyramids* with their pyramidal fasciculi, and at either side of the calamus scriptorius there are still to be seen the upper ends of the nuclei of the fasciculus cuneatus, and in this region also from fibers from the continuation of the posterior fasciculi, from parts of the lateral fasciculi and from arched transverse fibers from the olivary nucleus, the *cerebello-olivary fibers*, the *restiform body* (see page 169) which passes to the cerebellum is formed. Furthermore, there is a special bundle of longitudinal fibers in the dorsal part of the reticular white substance situated ventral to the hypoglossal nucleus, known as the *medial longitudinal fasciculus*: it courses upward to the mesencephalon in the region of the medial eminence of the rhomboidal fossa (see pages 161 and 184).

A very similar arrangement is shown by cross-sections through the medulla above the level of the calamus scriptorius (Fig. 666). Prominent on the surface are the *external arcuate fibers*, passing over the olives and the pyramids and separated from the surface of the latter by the gray *arcuate nuclei*. The nuclei of the posterior fasciculi are no longer present, and the lateral boundary of the rhomboidal fossa is formed by the restiform bodies. On the floor of the fossa, in addition to the nucleus of the ala cinerea, there is also a sensory glossopharyngeovagus nucleus and a motor nucleus for the same nerves, known as the *nucleus ambiguus*, occurs in the gray reticular substance dorsal to the olive. In this region also ganglion cells from which the upper root fibers of the accessory nerves arise are still to be found, and the posterior ends of the acoustic nuclei make their appearance, although these structures are more evident in cross-sections of the uppermost part of the medulla.

Cross-sections made through the rhomboidal fossa at the level of the medullary striæ (Fig. 667) show an arrangement which in many respects is similar to that seen in lower sections, although modifications occur. The olivary nuclei have decreased in size, while the pyramids, external arcuate fibers, and arcuate nuclei are about the same as in the inferior part of the rhomboidal fossa; indeed, the ventral part of the section differs only in its greater narrowness, which is espe-

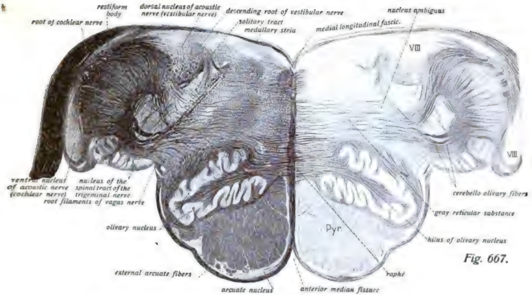


Fig. 667.

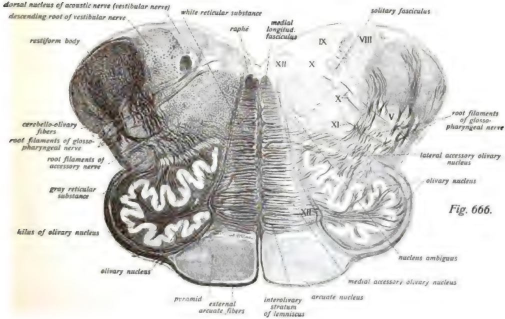


Fig. 666.

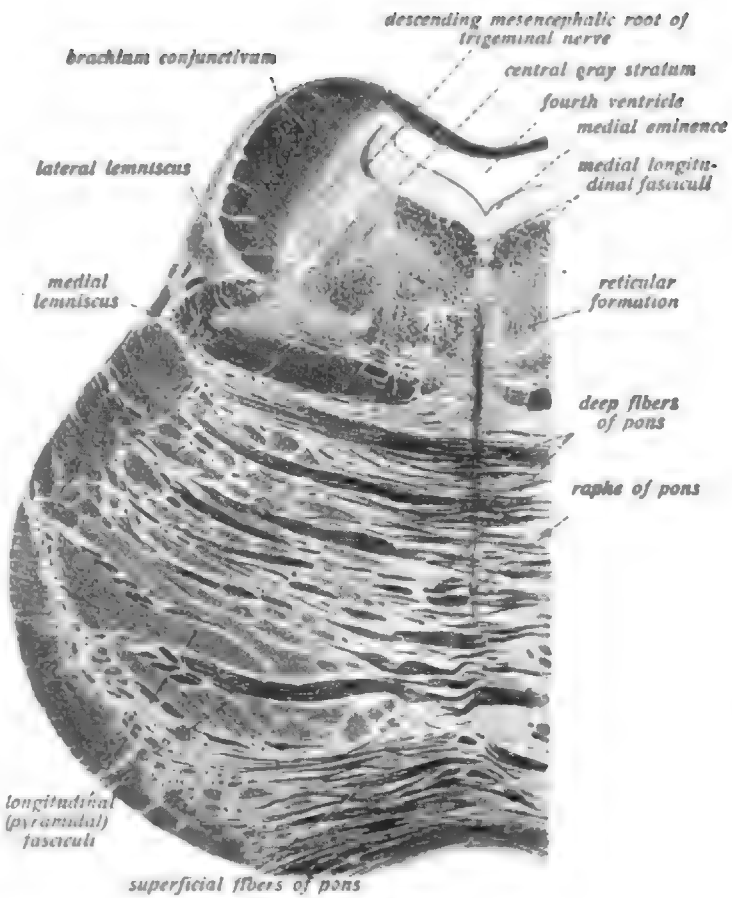


Fig. 669.

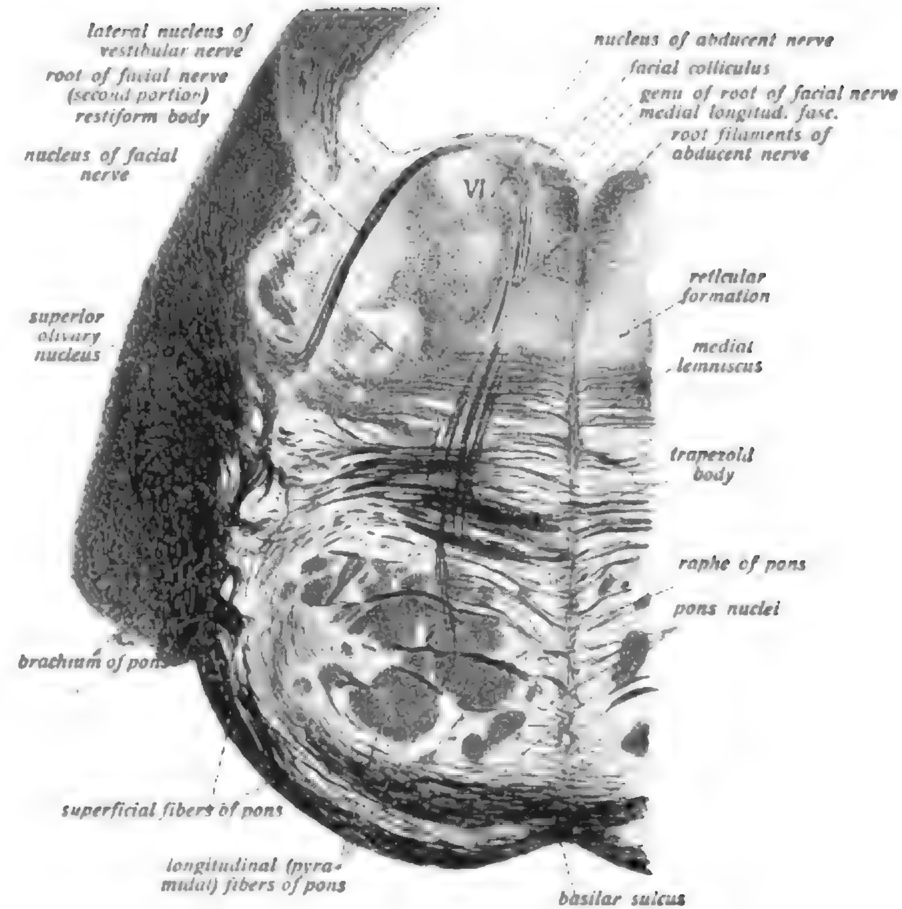


Fig. 668.

cially pronounced in the region of the interolivary stratum of the lemniscus. The restiform bodies now stand out strongly, and the floor of the fossa shows important changes and reaches at this level its greatest width. Just below the surface the *medullary striæ*, cut longitudinally, are noticeable; these belong to the acoustic nerve path, as does the rest of this region, which is accordingly called the *acoustic area.* It contains especially the nucleus of the acoustic nerve, which also, however, extends into the dorsal part of the pons. There is no distinct boundary in this dorsal region between the pons territory, that is to say, the metencephalon, and the medulla oblongata or myelencephalon. The *acoustic nerve* has separate nuclei for its two main portions, the *vestibular* and the *cochlear nerves*, so that a dorsal acoustic nucleus belonging to the vestibular nerve and a ventral belonging to the cochlear nerve can be recognized. The dorsal nucleus lies in the lateral part of the acoustic area of the rhomboidal fossa, while the ventral one is very superficial and close to the restiform body just where it enters the cerebellum. The dorsal nucleus is the *nucleus of the vestibular nerve*, which has another root known as the *descending* (*spinal*) *root*, as well as a lateral nucleus, Deiter's nucleus or the *lateral nucleus of the vestibular nerve*, lying to the medial side of the restiform body. The cochlear nerve passes principally to the ventral nucleus, but also sends fibers to the ganglion cells of the *acoustic tubercle* (dorsal cochlear nucleus), lying in the lateral recess of the rhomboidal fossa. The hypoglossal nucleus does not reach to the level of the medullary striæ, but the upper end of the vagus nucleus does..

In cross-sections of the pons (Figs. 668 and 669), two quite different portions may be recognized; the ventral or *basilar part* and the *dorsal part*, beneath the rhomboidal fossa. And since the latter is the direct continuation of the tegmentum of the cerebral peduncle, it is known as the *tegmentum of the pons.* The structure of the pons differs decidedly from that of the medulla. Among the most noticeable differences in the basilar part may be mentioned the absence of the olivary nuclei; the fasciculi of the pyramids are no longer seen on the surface as longitudinal fasciculi, but lie in the middle of the basilar portion as thick bundles, the *longitudinal fasciculi of the pons*, separated by gray masses, the *nuclei of the pons.* Ventrally as well as dorsally, they are bounded by rather large, transverse fiber tracts, the *superficial* and *deep fibers of the pons.* The raphe of the medulla oblongata is continued from the medulla into the pons, in the lower portion of which it extends into the basilar part, although in the upper portion it is limited to the dorsal part. The *dorsal part of the pons*, the tegmentum, lies between the rhomboidal fossa, on the one side, and the basilar portion on the other. In the region of the facial colliculus there is to be seen the *nucleus of the abducens nerve*, just below the surface of the fossa, the root fibers of the nerve taking origin from it and passing ventrally through the basilar part of the lower portion of the pons. A little further ventrally, and at the same time laterally, but still in the dorsal part is the *nucleus of the facial nerve*, from which the root fibers at first rise to the facial colliculus as the *first part of the root of the facial nerve*, and then curve around the abducens nucleus as the *internal genu of the facial nerve*, to course as the *second part of the root* laterally past the abducens and facial nuclei, between the superior olive and sensory nucleus of the trigeminal nerve, and appear on the ventral surface of the lower part of the pons. The dorsal acoustic nucleus and the sensory trigeminal nucleus, which increases in size upward, and also the motor nucleus of the trigeminus, which extends as far as the mesencephalon, with its mesencephalic root (see page 162), lie in the dorsal portion of the pons. In the lower portion there are also to be found the *superior*

olivary nucleus, medial to the second portion of the facial nerve and the ***nucleus of the trapezoid body*** (see below).

Of fiber tracts there are in the dorsal part of the pons, in addition to the mesencephalic and spinal trigeminal roots, first, the ***medial longitudinal fasciculus***, which has increased considerably in width compared with its condition in the medulla oblongata and lies close to the raphé below the facial colliculus, and really in the region of the medial eminence. From the reticular formation and especially from the interolivary stratum of the lemniscus there develops in the ventral portion of the dorsal part of the pons a broad, compact mass which becomes larger upward, the *lemniscus*. It divides (see page 162) at the rhombencephalic isthmus into a weaker lateral portion, the *lateral* (*acoustic*) ***lemniscus***, provided with a nucleus, the ***nucleus of the lateral lemniscus***, and a stronger medial portion, the ***medial lemniscus***, both parts, even the medial one, however, diverging from the median line toward the trigone of the lemniscus (see page 162). Finally, in the lowest portion of the dorsal part of the pons there are transverse fibers which decussate in the raphe; they belong to the acoustic nerve, and, passing over into the lateral lemniscus of the opposite side, are known as the ***trapezoid body*** (Fig. 668); they lie just above the deep fibers of the pons and include a small nucleus (see above).

THE MAIN TRACTS IN THE BRAIN.* THE TRACTS IN THE WHITE SUBSTANCE OF THE TELENCEPHALON.

In the white substance of the telencephalon three main groups of fiber tracts may be distinguished:

1. Tracts which unite regions of the cerebral cortex of the same hemisphere and are known as association fibers.

2. Tracts connecting identical points of the two hemispheres with one another and termed commissural fibers.

3. Tracts which pass from the cerebral cortex to or from deeper structures of the brain, such as the thalamus, corpora quadrigemina, cerebral peduncles, pons, medulla oblongata, or to the spinal cord. These are known as projection fibers.†

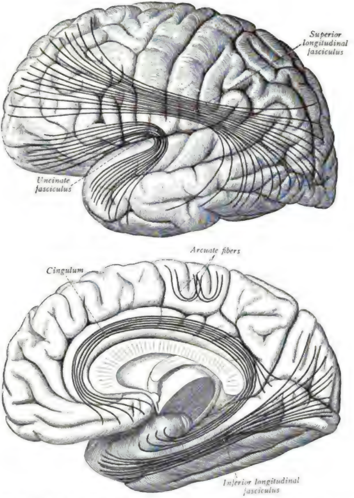
I. **Association Fibers.**—The association fibers (Figs. 670 and 671) are divided into two groups: (1) Into the short association bundles which unite neighboring cerebral convolutions and are called *cerebral arcuate fibers*, and (2) into those which connect more distant gyri or even lobes of the hemisphere, and constitute the long association bundles. Of the latter, four tracts have special names:

1. The ***cingulum*** (Fig. 671) courses in the medullary substance of the gyrus cinguli (and also the gyrus fornicatus), in the medial portion of the centrum semiovale, just above the lateral border of the corpus callosum, extending from the frontal lobe to the cuneus of the occipital lobe, and from there on along the hippocampal gyrus to the uncus of the temporal lobe.

2. The *fasciculus uncinatus* (Fig. 670), which is strongly curved, unites the orbital surface of the frontal lobe and the temporal pole, and in so doing courses in the floor of the anterior

* It does not fall within the scope of this outline to give an exact account of everything known regarding the cerebral fibers. Only the most important tracts will be discussed.

† Since the majority of the projection fibers belong to the so-called corona radiata (see below), they are also termed coronal fibers.



FIGS. 670 and 671.—The most important association tracts of the brain.

In Fig. 670 the fibers are projected upon the external; in Fig. 671 upon the mesial surface of the hemisphere (schematic).

part of the lateral cerebral fissure, that is to say, through the medullary substance of the gyri of the insula

3. The *superior longitudinal fasciculus* (Fig. 670) courses in the lateral portion of the semi-

oval center over the dorsal surface of the lenticular nucleus and between the gyri of the i. and the claustrum, from the frontal lobe through the operculum to the occipital and the poster. part of the temporal lobe.

4. The *inferior longitudinal fasciculus* (Fig. 671) connects the occipital lobe with the pole of the temporal lobe, coursing parallel with the inferior cornu of the lateral ventricle.

II. **Commissural Fibers.**—The commissural tracts are mainly represented by the corpus callosum, in addition to which only the anterior (not the posterior) and the hippocampal commissures are true commissures.

1. The *corpus callosum* has already been considered, as regards its external relations. Its fibers are divided into frontal, parietal, occipital, and temporal portions (see page 147).

2. The *anterior commissure* (Figs. 624, 632, 644, 648, and 650) is a horizontal, circular, sharply defined bundle, whose middle portion is situated in the anterior wall of the third ventricle in front of the columns of the fornix. Thence the commissure describes a curve, concave posteriorly, coursing along the inferior surface of the lenticular nucleus, its main, *posterior portion* passing to the temporal lobe, and its weaker, *anterior portion* extending to the olfactory lobe. Only that part of the commissure which lies in the anterior wall of the third ventricle is free; the remaining part is hidden in the substance of the hemisphere and is only visible in cross-section. The temporal, main portion of the commissure connects the hippocampal gyri of opposite sides.

3. The *hippocampal commissure* (see page 148) connects the two hippocampi. It is closely related to the fornix (see below) and is, therefore, also known as the transverse fornix.

III. **The Projection Fibers.**—The cerebral fibers known as projection fibers course from the cerebral cortex to deeper lying structures of the brain, and thus most of them pass through the internal capsule, where they form the so-called *corona radiata*. By corona radiata is meant the masses of fibers radiating into the cerebrum as the continuation of the cerebral peduncles, both the tracts coming through the base of the peduncles and those coming through the tegmentum, to which are added paths whose course is confined to the cerebrum itself and which come from the thalamus. As the fibers of the corona radiata pass from the internal capsule to the different portions of the cerebral cortex, they decussate extensively with the fibers of the corpus callosum radiation, and in the corona as well as in the callosal radiation, *frontal, parietal, occipital,* and *temporal portions* may be recognized.

The projection fibers represent paths of different lengths. The longest are the motor paths, which run from the cerebral cortex without interruption to the medulla oblongata and especially to the spinal cord, the longest fibers of these paths passing from the central region of the cortex to the inferior portion of the cord. The sensory paths are decidedly shorter, but also vary considerably in length; the longest are the cerebropontile tracts.

The most important parts of the corona radiata are as follows:

1. The motor path of the brain consists of two main portions, the pyramidal or cerebrospinal (corticospinal) tract and the motor tract of the cranial nerves, the corticobulbar tract.

(*a*) The *cerebrospinal tract fibers* (Figs. 642 and 672 to 675) arise in the cortex of the paracentral lobule and from the upper part of the central convolution. They occupy the anterior two-thirds of the posterior limb of the internal capsule and pass through the base of the cerebral peduncle, where they occupy the interval between the two cerebropontile tracts, through the pons

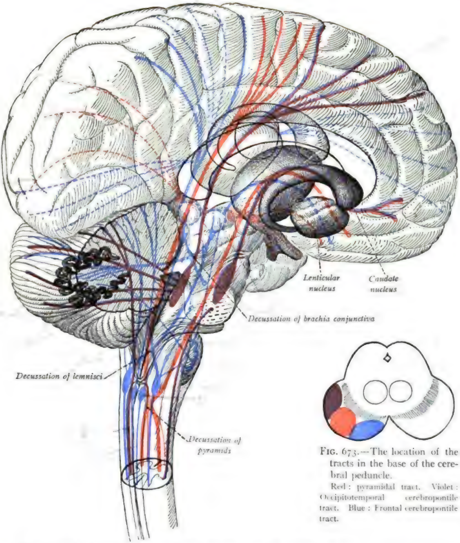


FIG. 673.—The location of the tracts in the base of the cerebral peduncle.

Red: pyramidal tract. Violet: Occipitotemporal cerebropontile tract. Blue: Frontal cerebropontile tract.

FIG. 672.—A schematic representation of some of the chief cerebral tracts.

Upon the left the entire cerebral hemisphere has been represented; upon the right, only the corpus striatum and lenticular nucleus. The right cerebellar hemisphere is supposed to have been removed. The following structures are indicated: the dentate nucleus of the cerebellum (black); the nuclei of the fasciculus gracilis, fasciculus cuneatus, and olive (blue); the red nucleus of the tegmentum (blue dotted); the pons nuclei (violet). The tracts represented are: the pyramidal tracts (red); the optic radiation (red dotted); the posterior columns of the spinal cord, the decussation of the fillet and its continuations, the central tegmental tract and the cerebello-olivary fibers (blue); the peduncle of the thalamus (blue dotted); the cerebellopontile, the cerebropontile, and the lateral cerebellar tract (violet).

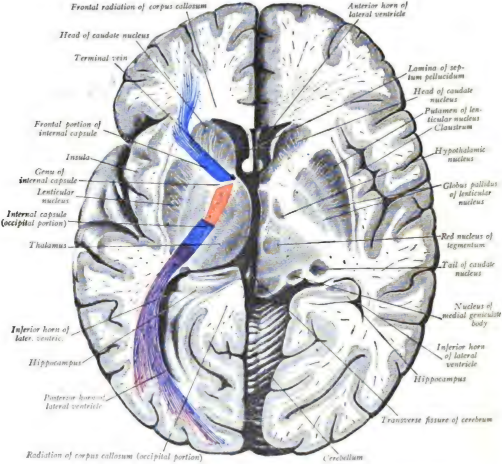


FIG. 674.—A horizontal section of the brain.

Upon the left side the section passes through the thalamus; upon the right, one centimeter deeper, through the corpora quadrigemina and the hypothalamic nucleus. In the left internal capsule are indicated the chief fasciculi of the corona radiata; the motor tracts are red (including the motor cerebral nerves); the sensory tracts blue, especially the cerebropontile tracts; the occipitothalamic radiation, violet. The frontal cerebropontile tract and the optic radiation are shown as far as their radiation into the cerebral cortex.

and the medulla oblongata to the pyramidal decussation. Here an incomplete decussation takes place, the main mass of fibers passing on the opposite side of the cord and terminating at different levels in the anterior gray column of that side, while a smaller, uncrossed part remains on the

original side as the anterior pyramidal tract (see page 116), and later on undergoes a crossing in the anterior white commissure.

(*b*) The ***corticobulbar tract*** has its origin (so far as is known) in the lower portion of the central convolutions, passes through the genu of the internal capsule and through the base of the cerebral peduncle to the various nerve nuclei situated in the opposite side of the medulla.

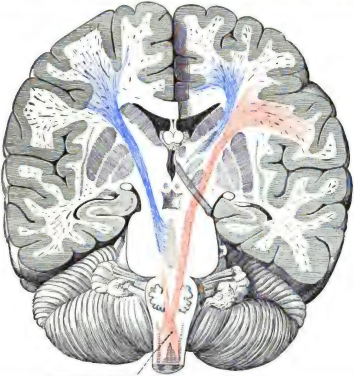


FIG. 675.—Certain tracts of the brain, particularly of the corona radiata, introduced into an outline of Fig. 642.

The pyramidal tracts are red; the cerebropontile and central tegmental tracts are blue.

2. The *cerebropontile tracts* (Figs. 672 to 675) connect the cerebral cortex with the nuclei of the pons (see page 175). They are divided into two separate portions, the frontal and occipito-temporal cerebropontile tracts.

(*a*) The fibers of the *frontal cerebropontile tract* arise in the cortex of the frontal lobe and pass through the anterior limb of the internal capsule and the medial portion of the base of the cerebral peduncle to the pons.

(*b*) The fibers of the posterior or *occipitotemporal cerebropontile tract* have their origin in the cortex of the temporal and occipital lobes and pass through the posterior limb of the internal capsule and the lateral portion of the base of the cerebral peduncle to the pons nuclei.

3. *The* (*Central*) *Tegmental Radiation.*—The majority of these fibers also pass through the internal capsule, lying in its posterior peduncle between the pyramidal tract and the posterior cerebropontile tract; a part of the radiation, however, takes its course through the lenticular nucleus and does not unite with the other fibers until later. The various fibers terminate in the cortex of the parietal lobe and come partly from the red nucleus of the tegmentum. A part of the fibers which take their course through the medullary lamellæ of the lenticular nucleus pass medially, at its base, partly to the ventral portion of the thalamus, partly to the hypothalamus (hypothalamic nucleus), and also continue onward to the red nucleus and the substantia nigra of the tegmentum and to the corpora quadrigemina. These fibers are collectively spoken of as the *lenticular ansa*, and together with the lower part of the inferior peduncle of the thalamus (see below) form the *peduncular ansa* (Fig. 646).

4. The *thalamic peduncles* (thalamocortical tract) form the connection between the thalamic ganglia and the cortex, and may be divided, according to their distribution, into an anterior, superior, posterior, and inferior thalamic peduncle. Together with fibers coming from the corpora quadrigemina and the lateral geniculate body they form the fibers passing to the cuneus of the occipital lobe and known as Gratiolet's *optic radiation* (Fig. 672), which passes through the most posterior portion of the posterior limb of the internal capsule.

In addition to these a number of less important tracts of the corona radiata, some of which are not yet thoroughly understood, pass from the cortex of the auditory center in the temporal lobe to the posterior corpora quadrigemina and the medial geniculate body, and others pass in a reverse direction, as the tegmental tract, from the cortex to the red nucleus. Furthermore, fibers passing from the cortex to the caudate and lenticular nuclei, and from these to the thalamus and hypothalamus, are known as the *radiation of the corpus striatum.*

PATHS OF THE RHINENCEPHALON,* THE HYPOTHALAMUS, AND EPITHALAMUS.

The paths of the rhinencephalon (Fig. 634) connect the primary centers of the olfactory lobe with the secondary centers in the hippocampal gyrus. They include the *lateral olfactory striæ* (see page 146), the *medial longitudinal stria* of the corpus callosum, and the olfactory bundle of the hippocampus, which has its course partly in the tract of the fornix.

To the fibers of the rhinencephalon belongs also the fornix, whose anatomical relations have been described above. It may be regarded as the coronal fasciculus of the hippocampus and rhinencephalon, just as the anterior commissure may be regarded as the commissural fasciculus (see page 178), and the cingulum (see page 176) (at least some of its longest fibers) as the association bundle, and a transverse connection of both cortical olfactory centers is also formed by the so-called transverse fornix or hippocampal commissure. In addition the fornix contains fiber tracts which come from the lateral longitudinal striæ of the corpus callosum and are known as the long fornix. The fornix fibers have their origin in the hippocampus and in the dentate gyrus and terminate mainly in the cells of the mammillary body.

Furthermore, fiber tracts run from the primary olfactory center to the deeper portions of the brain, such as the diencephalon, mesencephalon, and even the spinal cord.

In the region of the hypothalamus a few larger tracts, some of which are easily recognized macroscopically, may be found in relation with the mammillary body. The thalamomammillary fasciculus, mentioned above (page 159), arises from larger medial ganglion of the mammillary body and radiates into the anterior thalamic nucleus; a part of its fibers, however, passing as the tegmentomammillary fasciculus (Gudden's tegmental fasciculus) to the tegmentum of the cerebral peduncle.

* What is described anatomically as the rhinencephalon is the primary center of the olfactory radiation. The secondary or cortical center is to be found in the hippocampal gyrus.

In the habenular ganglion of the epithalamus, the *fasciculus retroflexus* (Meynert's) bundle arises, and passes thence to the interpeduncular ganglion.*

The Fiber Tracts of the Cerebellar Medullary Substance.

In the cerebellum, also, there are association fibers which connect the various cortical regions, and the connections of the cerebellum with the remaining portions of the brain are, as has already been indicated, through the cerebellar peduncles. The brachia conjunctiva contain fibers which arise in the dentate nucleus and pass partly to the red nucleus and partly to the thalamus, after undergoing decussation (see page 161); the brachia of the pons connect the pons nuclei with the cortex of the opposite cerebellar hemisphere; but the restiform body has a much more complicated structure.

It is composed of the following fiber tracts:

I. Those that terminate in the cerebellar cortex and are situated in the lateral portion of the restiform body. They are:

1. The *cerebellospinal fasciculus* ascending from the cord (see page 116).

2. Smaller fibers coming from the arcuate nuclei and the nuclei of the lateral fasciculus proprius.

3. Fibers from the nuclei of the posterior fasciculi, both of the same and the opposite side.†

4. The *cerebello-olivary fibers* (Figs. 666 and 672) which arise from the nuclei of the inferior olives of both sides, and form the main mass of the fibers of the restiform body which terminate in the vermis.

II. Those that end in the cerebellar nuclei, especially in the nucleus fastigii, and are regarded as sensory cerebellar paths, since they communicate with the sensory cerebral nerves. They lie in the medial portion of the restiform body and are divided into:

1. The *direct sensory cerebellar tract*, consisting of root fibers of various sensory cerebral nerves, especially of the trigeminus, which pass directly to the nucleus fastigii.

2. The *indirect sensory cerebellar tract*, consisting of fibers which connect the nuclei of the sensory cranial nerves in the medulla with the nucleus fastigii.

The Fiber Tracts of the Brain Stem.

In addition to the tracts mentioned above, which traverse the brain stem to a greater or less extent, such as the pyramidal and cerebropontile tracts, there are important paths belonging to the brain stem itself, and of these the most important is the *fillet* or *lemniscus* (Figs. 651, 652, 664 to 669, and 672), whose position has been already discussed (see page 172). Its fibers have their origin in the nuclei of the posterior fasciculi (nucleus gracilis and nucleus cuneatus), and as

* [As indicated above, the fasciculus retroflexus is probably to be regarded as a portion of the olfactory system, the habenular ganglion being in connection with the rhinencephalon by means of the tænia thalami. To the interpeduncular region, in which the fasciculus retroflexus terminates, fibers also pass from the auditory and optic centers, and all these three sensory tracts will find in this region possibilities for connection with the medial longitudinal bundle, which, with its prolongation in the spinal cord, the sulcomarginal bundle, may represent a direct reflex path for special sense stimuli.—Ed.]

† These fibers pass partly directly to the cerebellum and partly decussate with the lemniscus fibers in the raphe of the medulla and then pass as external arcuate fibers (see page 173) over the ventral surface of the medulla to the restiform body.

internal arcuate fibers pass toward the median line, cross in the decussation of the lemniscus, and further on in the raphé of the medulla oblongata, and form the ventral part of the interolivary stratum of the lemniscus. In the region of the pons, more precisely in the ventral portion of its dorsal part, they form a more compact bundle and diverge more and more from the median line, and the tract known as the *medial lemniscus* * penetrates into the tegmentum of the cerebral peduncle and through it to the lateral thalamic nucleus. This tract is strengthened partly by fibers ascending directly from the cord, and especially by fibers which come from the sensory nuclei of the trigeminal, glossopharyngeal, and vagus nerves.

In addition to the medial lemniscus, a special tract lying dorsal to it, the *medial longitudinal fasciculus*, must be mentioned. It extends as a longitudinal bundle, situated close to the median line (see page 176), from the mesencephalon (*nucleus of the medial longitudinal fasciculus*, page 159) to the spinal cord. It is strengthened considerably by fibers coming from the so-called Deiter's nucleus or *nucleus of the lateral vestibular nerve*, which, crossing the median line, pass in the fasciculus of the opposite side, partly centrifugally to the spinal cord and partly centripetally to the mesencephalon. In addition the median longitudinal fasciculus communicates by numerous collateral branches with the nuclei of the nerves of the eye muscles.†

The remaining tracts of the brain stem, the lateral lemniscus included, are either parts of cranial nerve paths or have been already mentioned in the description of the restiform body (page 183).

Nuclei and Paths of the Cranial Nerves.

As a conclusion to the description of the brain the origins and courses of the twelve pairs of cranial nerves may be briefly described:

1. The first or *olfactory nerve* passes in the form of numerous soft, gray, non-medullated fibers through the lamina cribrosa of the ethmoid into the upper part of the nasal cavity (see Vol. II, page 87). Its fibers arise from the olfactory cells of the nasal mucous membrane

2. The *optic nerve* (Figs. 647 and 649) arises from the optic chiasma, the optic part of the hypothalamus. This represents an incomplete decussation of the two optic tracts, which enter the thalamus and metathalamus by two roots. The origin of the optic nerve-fibers is in the ganglion cells of the retina and from these the fibers pass through the optic nerve to the chiasma, where most of them cross and traverse the optic tract to the primary optic centers, which are in the pulvinar, superior corpora quadrigemina, and lateral geniculate body (see pages 157, 158, and 159). ‡

3. The *oculomotor nerve* (Figs. 676 and 677) is purely motor. It arises at the floor of the cerebral aqueduct from a shorter, small-celled median and longer, larger-celled lateral nucleus. Its fibers pass through the tegmentum to the sulcus of the oculomotor nerve, where they unite to form the nerve trunk. The nerve on either side contains not only fibers from the median nucleus, but also from both lateral nuclei.

* The lateral lemniscus (fillet) is a part of the acoustic path (see page 187).

† See footnote on page 183.

‡ There are also fibers in the optic nerve which pass from the retina directly to the cortex of the cuneus (the secondary optic center) without traversing the primary centers, and others which arise from the primary centers and pass centrifugally to the retina.

4. The *trochlear nerve* (Figs. 676 and 677) is also purely motor, and has its origin in the nucleus of the trochlear nerve situated in the floor of the cerebral aqueduct. The roots of both sides cross in the anterior medullary velum, forming the *decussation of the trochlear nerves,* and make their exit on either side, lateral to the frenulum of the anterior medullary velum.

5. The *trigeminal nerve* (Figs. 676 to 678) consists of a smaller motor part, the *portio minor* and a larger sensory part, the *portio major.* The motor root arises from a main nucleus lying in the dorsal part of the pons, and also as a *descending* (*mesencephalic*) *ramus* from the

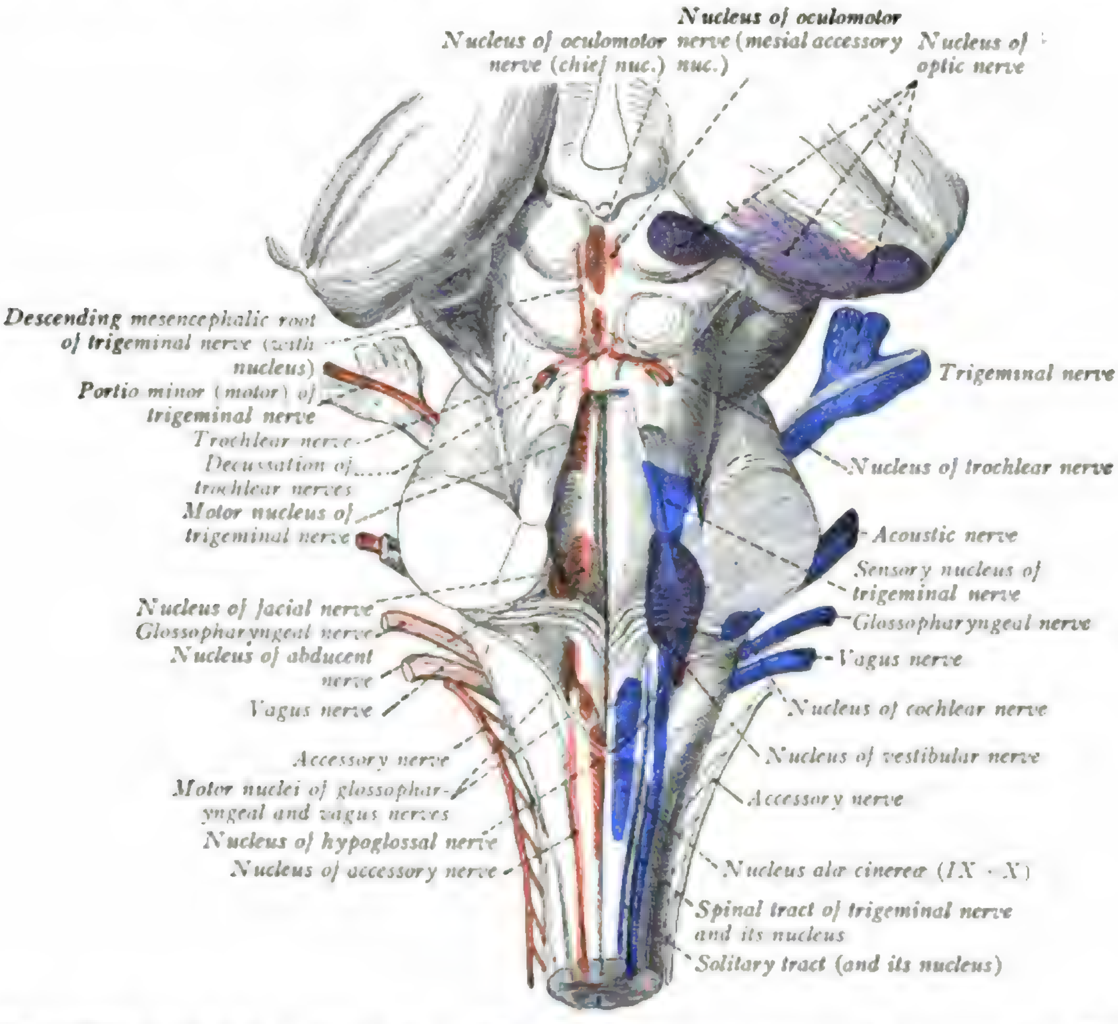


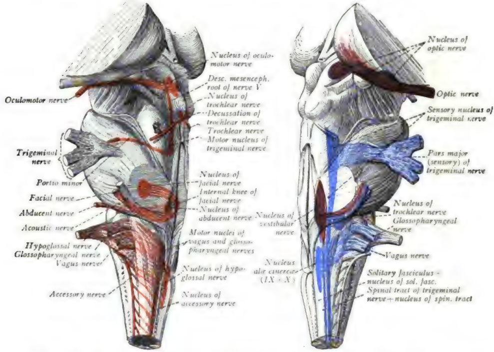
FIG. 676.—The nuclei of the second to the twelfth cerebral nerves schematically introduced into Fig. 660.
Sensory nuclei, blue; motor, red. Of the sensory nuclei, those of the optic and vestibular nerves are violet; that of the cochlear nerve, blue. The motor nuclei are depicted upon the left, the sensory upon the right.

nucleus of the descending root in the mesencephalon and from cells of the locus cœruleus. Its root fibers form the minor portion (see page 194).

The sensory fibers arise from the *semilunar* (*Gasserian*) *ganglion* (see page 194) in a manner similar to the roots of the sensory spinal nerves (see page 121). The fibers enter the substance of the pons and here divide into ascending and descending fibers; the former go to the sensory

main nucleus in the pons, while the latter form the *spinal tract* and pass to its nucleus, which is the caudal prolongation of the nucleus situated in the pons, and as the gelatinous substance (Rolando) extends into the cervical part of the spinal cord. For its connections with the cerebellum, see page 183. From the sensory nucleus the fibers pass to the thalamus by way of the medial lemniscus.

6. The *abducens nerve* (Figs. 668, 676, and 677), also a purely motor nerve, arises from the nucleus of the abducens nerve situated in the rhomboidal fossa (see page 175). Its root fibers pass ventrally to make their exit at the lower border of the pons.



FIGS. 677 and 678.—Representations of the nuclei of the second to the twelfth cranial nerves, as viewed from the left and from the right.

In Fig. 677 the motor nuclei and roots are indicated in red (the root fibers of the hypoglossal nerve, red dotted); in Fig. 678 the sensory nuclei and roots are colored blue, except that of the vestibular and optic nerves, which are violet.

7. The *facial nerve* (Figs. 668, 676, and 677) is purely motor and arises from the nucleus of the facial nerve in the dorsal part of the pons. Its root fibers arch around the abducens nucleus, and a distinction is made between the *first part of the root,* which ascends dorsomedially from

the nucleus to the region of the facial colliculus; the *internal genu*, which forms the bend just below the surface of the rhomboidal fossa; and the ventrally directed *second part of the root*, which emerges between the posterior border of the pons and the upper border of the olive.

7a. The *intermediate nerve* (*nerve of Wrisberg*) courses for a distance along with the facial nerve. It is sensory (see page 205) and arises in the *geniculate ganglion* of the facial nerve and passes by its centripetal nerve prolongations to the nuclei of the glossopharyngeal nerve, and especially to the *nucleus of the solitary tract.**

8. The *auditory nerve* (Figs. 667 and 676 to 678) consists of two parts with decidedly different origins, the cochlear and vestibular nerves.

The *cochlear nerve* is a sensory nerve which arises from the *spiral ganglion of the cochlea* (see page 284). The centripetal continuations of the nerve cells of the ganglion enter the upper portion of the medulla close to the exit of the facial nerve and pass to the *ventral acoustic nucleus*, which represents the ventral cochlear nucleus, and to the ganglion cells of the *acoustic tubercle*, the dorsal cochlear nucleus. From these nuclei the cochlear path passes as the *lateral lemniscus* to the medial geniculate body and the posterior corpora quadrigemina, and is composed of—1. The *trapezoid body*, a path coming from the ventral nucleus and crossing the median line (see page 176); 2. The *medullary striæ* of the rhomboidal fossa and some neighboring fibers, which curve around the restiform body and before entering the lateral lemniscus pass to the opposite olive, decussating in the raphé.

The *vestibular nerve* has its origin in the vestibular ganglion, and its fibers pass to the brain together with those of the cochlear nerve and with them enter the medulla oblongata, in which, however, they pass to different nuclei, which form the *dorsal nucleus* of the acoustic nerve. Four of these nuclei can be recognized, a *medial nucleus*, lying in the acoustic area of the rhomboidal fossa, a neighboring *superior nucleus* (Bechterew's nucleus), a more lateral and somewhat deeper *lateral nucleus*, and the *spinal nucleus*, which extends to the lower end of the medulla oblongata. The fibers passing to the latter nucleus are known as the *spinal acoustic root*. A part of the root fibers of the vestibular nerve go directly to the cerebellum (see page 183).

9 and 10. The *glossopharyngeal* and *vagus* (Figs. 676 to 679) are mixed nerves, and have common nuclei in the medulla. Each consists of a motor and a sensory part, the motor part of both nerves arising in the motor nucleus of the glossopharyngeus and vagus in the floor of the rhomboidal fossa and from the nucleus ambiguus.

The sensory fibers come from the *superior* and *petrosal* (*IX*) and the *jugular* and *nodose* (*X*) *ganglia*, whose centripetal processes pass partly to the *nucleus of the ala cinerea*, and partly descend as the *solitary tract*, to the *nucleus of the solitary tract*. From these fibers pass to the thalamus in the medial lemniscus.

11. The *accessory nerve* (Figs. 676 and 677) is purely motor. Its nucleus is narrow and elongated and extends from the fifth or seventh cervical segment of the spinal cord, where it appears as a group of ganglion cells in the lateral portion of the anterior gray column, upward to the middle part of the medulla, where its nucleus is situated in the lateral portion of the reticular

* [The intermediate nerve is usually regarded as the sensory part of the facial nerve, which then belongs to the category of mixed nerves.—ED.]

FIG. 679.—The dura mater with its arteries and sinuses, the veins of the orbit, and the course of the twelve pairs of cerebral nerves through the dura mater.

The left orbit has been opened. Upon the right the tentorium cerebelli has been removed, the commencement of the transverse sinus opened, and the dura mater excised along the emerging nerves and the middle meningeal artery. * – Meningeal nerve and anastomosis with the spinal nerve. ** – Cut edge of tentorium.

formation. The root fibers emerge as a number of small bundles from the region of the lateral funiculus.*

12. The *hypoglossal nerve* (Figs. 676 and 677) is also motor, and its nucleus is situated in the *trigone of the hypoglossal nerve* in the rhomboidal fossa. The root fibers pass ventrally between the medial accessory olive and olive to the groove between the pyramid and olive.

THE MEMBRANES OF THE BRAIN.

In the brain we recognize the same membranes as in the spinal cord—namely, the *dura mater*, the *arachnoid*, and the *pia mater*.

The *encephalic dura mater* (Figs. 589 and 679 to 681), although it is practically a direct extension of the spinal dura from the foramen magnum, differs from it by being somewhat thicker, and especially because at the same time it forms the inner periosteal layer of the cranium, and is thus formed of two laminæ, the periosteal and the dural, which are for the most part completely fused.

The dura mater has a shining whitish color and is composed of crossed oblique and longitudinal fibers, and lies closely upon the inner surface of the cranial fossa, of which it takes an exact impression. It varies somewhat in thickness; where it passes through foramina of the skull with vessels and nerves it decreases remarkably in thickness, forming sheaths for the emerging nerves.

In addition to forming an internal lining for the cranium, it has three processes which extend between separate portions of the brain and partly serve as supports for it. The whole surface of the dura facing the cranial fossa, as well as both surfaces of the flat processes, are quite smooth and glossy, while the surface lying next the cranial bones and serving as their periosteum is uneven and rough, especially at the base of the cranium, where it is more closely adherent to the bone than on the inner surface of the roof, numerous small blood-vessels penetrating from the dura mater into the cranial bones.

In certain regions the two laminæ of the dura separate to enclose smooth cavities and canals, of which the most important are the *sinuses of the dura mater*, the large blood-vessels of the dura mater (see page 85). Another large cavity of the dura is the space which encloses the semilunar ganglion of the trigeminal nerve, the so-called Meckel's cavity. A large dural process extends into the subarcuate fossa of the temporal bone and fills its cavity completely.

Special formations of the encephalic dura mater are:

1. *The Diaphragma Sellæ* (Fig. 679).—While a thin lamina of dura covers the floor of the sella turcica, a lamina perforated at the center extends transversely across it and connects the anterior and posterior clinoid processes; this is the *diaphragm of the sella*. It separates the

* [The accessory nerve is morphologically a portion of the vagus, and bears to that nerve somewhat the same relation that the descending or mesencephalic root of the trigeminus does to its nerve.—ED.]

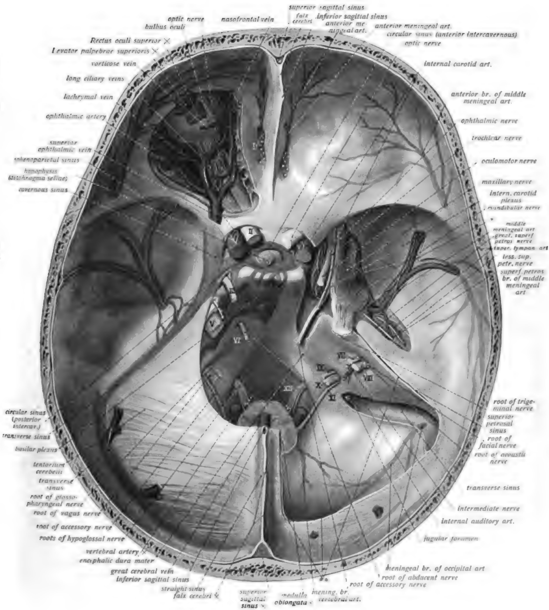

superior sagittal sinus
falx cerebri
inferior sagittal sinus
optic nerve
nasofrontal vein
anterior meningeal art.
anterior meningeal art.
bulbus oculi
circular sinus (anterior intercavernous)
optic nerve
Rectus oculi superior ×
Levator palpebrae superioris ×
vorticose vein
internal carotid art.
long ciliary veins
lachrymal vein
anterior br. of middle meningeal art.
ophthalmic artery
ophthalmic nerve
trochlear nerve
superior ophthalmic vein
sphenoparietal sinus
oculomotor nerve
hypophysis (diaphragma sellae)
cavernous sinus
maxillary nerve
intern. carotid plexus
mandibular nerve
middle meningeal art
great. superf petros nerve
super. tympan art
less. sup. petr. nerve
superf. petros br. of middle meningeal art
I
II
IV
V
VI
VII
IX
VIII
X
XII
XI
circular sinus (posterior intercav.)
transverse sinus
basilar plexus
tentorium cerebelli
transverse sinus
root of glosso-pharyngeal nerve
root of vagus nerve
root of accessory nerve
roots of hypoglossal nerve
vertebral artery ×
encephalic dura mater
great cerebral vein
inferior sagittal sinus
straight sinus
falx cerebri ×
superior sagittal sinus ×
medulla oblongata
mening. br. vertebral art.
root of trigeminal nerve
superior petrosal sinus
root of facial nerve
root of acoustic nerve
transverse sinus
intermediate nerve
internal auditory art.
jugular foramen
meningeal br. of occipital art
root of abducent nerve
root of accessory nerve

Fig. 679.

hypophysis from the rest of the brain, except for its connection through the infundibulum, which passes through the central perforation, the *foramen of the diaphragm*.

2. *The Falx Cerebri* (Figs. 589, 680, and 681).—This is the largest of the three processes projecting from the dura into the cranial fossa, and is attached by one border to the dura of the roof of the skull, while the other concave border is free. It forms a sickle-shaped sagittal plate, which dips into the longitudinal cerebral fissure and terminates with its free edge just above the surface of the corpus callosum. Its anterior end is fastened to the crista galli of the ethmoid, its upper convex border separates into two diverging laminæ, which are attached to the frontal crest and to the borders of the sagittal sulcus down to the cruciate eminence, and with the parietal dura they bound the superior sagittal sinus (see page 85). The free concave border, which lies above the corpus callosum, is considerably shorter than the upper convex border, since anteriorly it is attached to the crista galli and posteriorly it unites with the upper surface of the tentorium (see below). Along this line of attachment also the two laminæ of the dura separate, and with the surface of the tentorium form the straight sinus (see page 85).

3. The *tentorium* (Figs. 589 and 679 to 681) is a roof-like plate of dura stretched over the posterior cranial fossa and separating the cerebellum from the inferior surface of the cerebral hemispheres. It has its origin on either side, first, from the superior angle of the pyramid of the temporal bone, and, while passing over the foramen lacerum, also from the posterior clinoid process, and second, from the upper border of the transverse sulcus. The two halves of the tentorium meet at an oblique angle in the median line, forming a low roof-like ridge with which the posterior portion of the lower border of the falx cerebri unites. In front of this union the two halves of the tentorium are separated by an oval opening, bounded anteriorly by the sella turcica and laterally and posteriorly by the free medial border of the tentorium. In this opening, the *tentorial notch*, lie the pons and quadrigeminal plate of the cerebrum, the posterior border of the notch corresponding to the posterior end of the transverse cerebral fissure. The upper surface of the tentorium is moderately convex, the lower concave, and along its line of attachment it forms anteriorly the superior petrosal sinus, and posteriorly the transverse sinus (page 85).

The *falx cerebelli* (Fig. 580) is a short process of the dura mater, broad above and narrow below, which projects into the posterior cerebellar notch and the vallecula between the two cerebellar hemispheres. It has its origin at the internal occipital crest and is attached above to the tentorium. In its lower portion it diminishes very rapidly in height and ends frequently in two diverging limbs.

The *encephalic arachnoid* (Figs. 680 and 681) is a delicate membrane, resting upon the brain. In contrast to the pia mater it passes over all the depressions of the brain surface, not only over its fissures, but also over the deep groove and cavities of the base of the brain. Its external surface is separated from the dura only by a narrow space, the *subdural cavity*, but from the pia mater, which fits tightly upon the surface of the brain, it is partly separated by relatively large spaces, while at other prominent portions of the surface both laminæ lie close together. The space which separates the pia mater from the arachnoid is the *arachnoideal cavity*, containing the arachnoideal fluid or the external *cerebro-spinal fluid* *), and is separated into a number of large portions, which communicate with one another and are separated by relatively short intervals.

* The real cerebrospinal liquor is that which fills the internal cavities of the central nervous system.

The wide recesses of the subarachnoideal space are situated especially where the arachnoid bridges depressions of the surface of the brain, and they are known as the ***subarachnoidal cisterns.*** Of these, the following bear special names:

1. The *cerebello-medullary cistern* lies between the medulla oblongata and the cerebellar hemispheres and corresponds to the cerebellar vallecula, which it covers.

2. The *cistern of the lateral cerebral fossa* over the fossa of that name.

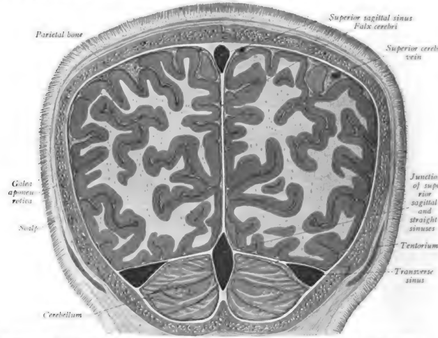


FIG. 680.—A frontal section of the head in the region of the posterior fourth of the sagittal suture. Dura mater, white; pia mater, blue.

3. The *interpeduncular cistern* corresponds to the interpeduncular fossa, and communicates with the following:

4. The *chiasmatic cistern* is between the optic chiasma and the rostrum of the corpus callosum.

5. The *cistern of the great cerebral vein* is posterior and inferior to the body of the corpus callosum and superior to the quadrigeminal plate.

The *arachnoidal granulations* (Pacchionian bodies) are villus-like outgrowths of the arachnoid, which may be found especially on the surface of the cerebrum along the sagittal sinus, but may also occur near the transverse sinus over the cerebellum. In normal development they project into the sinus, but if strongly developed, as they frequently are in old age, they may

pierce the dura mater and produce granular foveolæ (see Vol. I, page 44) on the inner surface of the cranial roof.

The *encephalic pia mater* (Figs. 680 and 681) is thinner than the spinal pia mater and resembles it in its relation to the surface of the brain only in the region of the brain stem. In this region the pia is tougher than elsewhere and fits tightly to the surface of the brain, but it may easily be stripped from the surface of the cerebral and cerebellar convolutions. It penetrates into all the surface fissures and lines them, and in it the larger and medium-sized blood- as well as lymph-vessels of the brain have their course.

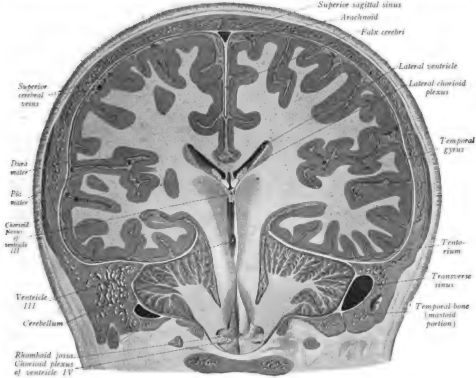


FIG. 681.—A frontal section of the head in the region of the anterior portion of the sagittal suture. Dura mater, white; pia mater, blue.

Among the special formations of pia mater are, in the first place, the *chorioidal plexuses* (Figs. 636, 638, 641, 646, and 681) already mentioned, which are folds of pia mater containing a rich vascular plexus, which project into the ventricles of the brain. Generally, they appear

in the form of much-twisted bands, which, judging from their development, must be regarded as folds of pia mater. They are separated from the ventricular cavity by the epithelial chorioidal laminæ which cover their surfaces with all their projections and indentations. The more minute relations of the various plexuses have already been described in the description of the brain itself. In the second place the *chorioid tela* must be mentioned. They are duplications of the pia mater, which complete the wall of parts of the ventricles where no nerve tissue is developed. Here also, the pia mater is not directly in contact with the ventricular cavity, but is separated from it by an epithelial lamina.

THE BLOOD VESSELS OF THE BRAIN AND THE VESSELS AND NERVES OF ITS MEMBRANES.

The **arteries** of the brain (Figs. 548 and 549) come partly from the internal carotid and partly from the vertebral artery (see pages 30 and 35). Both anastomose with one another, as well as with the arteries of the other side of the brain, more extensively than is the case with any other artery of the body, the four large cerebral arteries, which are the sole supply of the brain, forming double anastomoses with one another, which lie in the region of the arterial circle (see page 37). On the other hand, the arteries coming from the pia and penetrating even into the substance of the brain are so-called terminal arteries, that is, they have only a capillary anastomosis. The branching of the arteries always takes place from the pia mater, that is, from the free surface, and the gray substance of the brain, like that of the spinal cord, has an extraordinarily rich blood-supply, while the white substance is relatively poorly supplied.

The **veins** of the brain (Fig. 590) do not follow the course of the arteries, and differ from the other veins of the body by opening into the sinuses of the dura mater (see page 88).

True **lymphatic vessels,** so far as is known, are not found in the brain. The perivascular sheaths are regarded as lymph spaces, as are also the subarachnoideal and subdural spaces.

The blood vessels of the membranes are divided into those of the dura mater and those of the pia mater. The latter are identical with those of the brain; the arachnoid has no vessels and the **arteries** of the dura (Fig. 679) are known as meningeal arteries. Their course is in its external layer, next to the bone, on which they leave furrows. They arise as follows: 1. From the middle meningeal artery of the internal maxillary (page 28), the main artery of the meninges; 2. The anterior meningeal from the anterior ethmoidal (page 32), to the dura in the anterior cranial fossa; 3. The posterior meningeal from the ascending pharyngeal (page 24) for the dura near the jugular foramen; 4. The mastoid meningeal branch of the occipital (page 25) for the dura of the posterior cranial fossa; 5. The meningeal branch of the vertebral (page 36) for the dura about the foramen magnum.

The meningeal **veins** only partly follow the course of the arteries (double meningeal veins (page 89) accompanying the middle meningeal artery). Many small meningeal veins open into the dural sinuses directly, and they anastomose, as do the dural sinuses, with the external cranial veins and with the veins of the diploe through emmissary veins.

Lymphatic vessels are found in the pia mater only.

The **nerves** of the pia mater are very delicate; those of the dura are more numerous. The latter originate mainly from the three branches of the trigeminus, and are the tentorial nerve from the ophthalmic division, the meningeal from the maxillary division, and the recurrent spinous nerve from the mandibular division. The meningeal branch of the vagus also supplies the dura mater.

THE PERIPHERAL NERVOUS SYSTEM.

The peripheral nervous system comprises the ramifications of the nerves which emerge from the brain and spinal cord, that is to say, the ramifications of the twelve cerebral and thirty-one spinal pairs of nerves. The system may be divided, therefore, into the *cerebral* and the *spinal nerves.*

THE CEREBRAL NERVES.

According to the usual enumeration there are twelve pairs of cerebral nerves, the olfactory nerves, being together considered as one, and the intermediate nerve being regarded as part of the facial. The twelve cerebral nerves are then as follows:

1. The *olfactory nerve.*
2. The *optic nerve.*
3. The *oculomotor nerve.*
4. The *trochlear nerve.*
5. The *trigeminal nerve.*
6. The *abducens nerve.*
7. The *facial nerve* (+ the *intermediate*).
8. The *acoustic nerve.*
9. The *glossopharyngeal nerve.*
10. The *vagus nerve.*
11. The *accessory nerve.*
12. The *hypoglossal nerve.*

Of these, the purely motor nerves are: the oculomotor, the trochlear, the abducens, the facial (without the intermediate), the accessory, and the hypoglossal. Three are sensory: the olfactory, the optic, and the acoustic; the remaining three, the trigeminal, the glossopharyngeal, and the vagus, are mixed. The origin of these nerves in the brain, as well as their exit, has already been discussed; their course and ramification from the base of the brain are now to be described. Since the three sensory nerves will be discussed with the respective sense organs in this chapter, the other nine nerves only need be considered here.

THE NERVES OF THE EYE MUSCLES.

The third, fourth, and sixth cerebral nerves go to the eye muscles and represent their motor nerves. They resemble anterior roots of the spinal nerves and are homologous to them.

The **oculomotor nerve** (Figs. 546, 547, 679, 682, and 683) arises at the base of the brain by root filaments which appear in the sulcus of the oculomotor nerve. These form at first a flat, and then a rounded, nerve which passes between the posterior cerebral and superior cerebellar arteries. It pierces the dura mater on the medial side of the posterior clinoid process and enters the cavernous sinus (page 86), in which it passes forward and a little laterally to the superior orbital fissure, lying lateral to the internal carotid artery and anastomosing by delicate rami with the carotid sympathetic plexus. It enters the superior orbital fissure on the lateral side of the optic nerve, but lies medial to the abducens and inferior and medial to the ophthalmic nerve.

In the superior orbital fissure the nerve divides into an upper, weaker, and a lower, stronger branch. The *superior ramus* passes above the optic nerve to the levator palpebræ superioris and to the superior rectus muscles, the stronger *inferior ramus* branches below the optic nerve and gives off rami to the inferior rectus, the medial rectus, and inferior oblique, and it also gives a short, but rather strong, branch to the ciliary ganglion, the *short root of the ciliary ganglion.*

The **trochlear nerve** (Figs. 546, 547, 679, 682, and 683) leaves the brain close to the frenulum of the anterior medullary velum (see page 160). It is a very long and very thin nerve, which, before entering the orbital cavity, has a remarkably long course. From its origin from the rhombencephalic isthmus the nerve winds about the brachia conjunctiva and cerebral peduncle to the ventral side of the brain, where it comes to view between the pons and the medial border of the temporal lobe. It then pierces the dura mater behind the posterior clinoid process and passes through a narrow canal in the upper lateral wall of the cavernous sinus. In so doing it crosses the oculomotor nerve at its entrance into the dura mater, having been to the lateral side of that nerve up to the point mentioned and it then comes to lie medially and above the semilunar ganglion of the trigeminal and th[illegible]halmic nerve. In the orbital cavity the trochlear nerve

FIG. 682.—The nerves and arteries of the orbit (superficial layer).

The roof of the orbit, the periorbita, and the upper portion of the outer wall have been removed. The dura mater has been divided along the middle meningeal artery and in the neighborhood of the semilunar ganglion and of the orbital nerves. * – Accessory vessels to the lachrymal gland from the zygomatico-orbital branch of the anterior deep temporal artery. ** – Orbital fat.

FIG. 683.—The nerves and arteries of the orbit (second layer).

The dissection the same as in Fig. 682, except that the greater protion of the frontal branch of the ophthalmic nerve has been excised, the orbital fat on the outer side partly removed, and the rectus superior and levator palpebræ superioris drawn to one side.

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lies quite superficial, below the periorbita of the roof of the cavity, and passes forward and medially to the superior oblique muscle, into which it enters from above and medially.

The **abducens nerve** (Figs. 546, 547, 679, 682, and 683) leaves the brain in the fissure between the anterior end of the pyramid of the medulla oblongata and the posterior border of the pons. It penetrates the dura mater in the posterior cranial fossa, or more precisely, on the lateral surface of the clivus, and sinks into the cavernous sinus, through which it passes for a long distance almost horizontally, lying closely lateral to the internal carotid artery, and so reaches the superior orbital fissure. It is a comparatively large nerve, being twice the thickness of the trochlear, and sends several fibers to the sympathetic plexus of the internal carotid. From the anterior end of the cavernous sinus it enters the orbit below and lateral to the ophthalmic nerve and courses below the lachrymal nerve, in the upper part of the orbital cavity, to the medial surface of the lateral rectus muscle, which it supplies.

THE TRIGEMINAL NERVE.

The trigeminal nerve (Figs. 541 to 547, 591, 592, 679, 682 to 687, and 689 to 692) is the strongest of all the cerebral nerves; it emerges from the brain at the anterior border of the base of the brachium of the pons and is divided into a weaker motor portion, the *portio minor*, and a stronger sensory portion, the *portio major*. The root fibers of the portio major are collected into a reticular flat fasciculus, while the minor portion, in the form of a more compact bundle, rests upon the medial surface and the anterior border of the sensory root. The nerve trunk so formed passes anterolaterally through an elongated, oblique opening of the dura mater at the root of the tentorium, behind the posterior clinoid process, and comes to lie in Meckel's cavity of the dura, a flat space situated lateral to the cavernous sinus, whose floor is formed by the trigeminal impression on the pyramid of the temporal bone, covered by dura mater. Here the portio major enters a flat, plexiform, somewhat triangular ganglion, the *semilunar (Gasserian) ganglion* (Figs. 546, 547, 623, 679, 682, 683, 689, and 690), which is rather closely united to the dura mater. As is the case with the spinal ganglia, with which the semilunar ganglion is homologous, only the sensory root takes part in its formation, and only its fibers having their origin in the ganglion (see page 186). The motor minor portion passes by the ganglion, just as the motor roots of the spinal nerves pass the spinal ganglia, and courses obliquely over its medial surface, in order to unite with the third branch coming from the ganglion.

From the lateral anterior border of the semilunar ganglion three flat nerve stems make their exit, which at first continue to show the plexiform character of the trunk. The most anterior

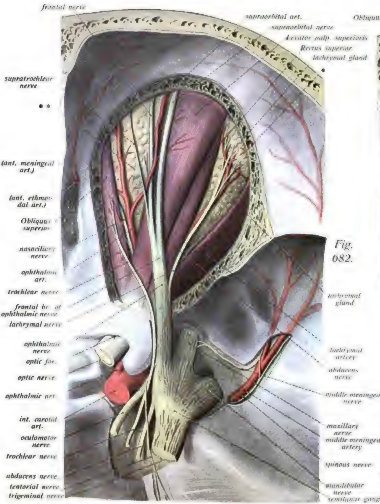


Fig. 682.

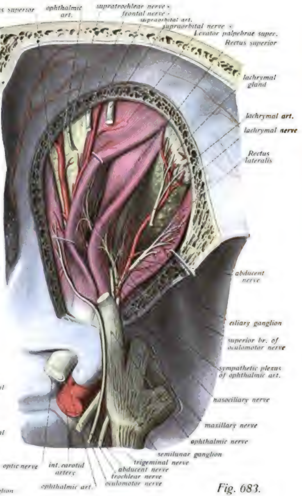


Fig. 683.

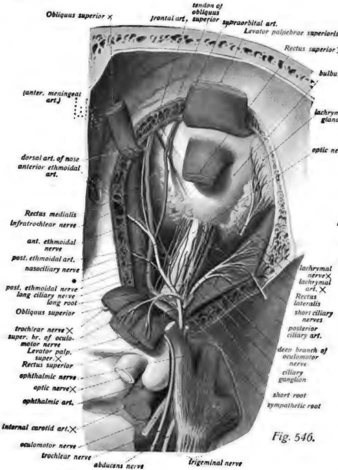


Fig. 546.

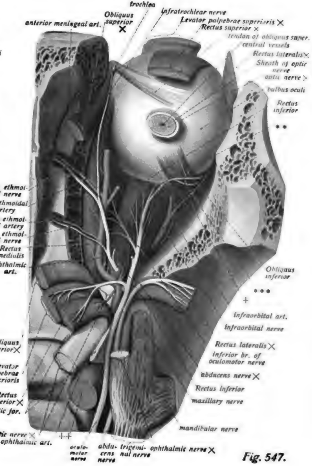
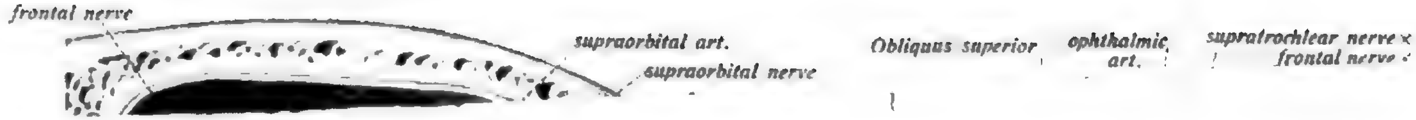


Fig. 547.



frontal nerve
supraorbital art.
supraorbital nerve
Obliquus superior
ophthalmic art.
supratrochlear nerve
frontal nerve

to the superior lachrymal gland, and then passes between the lobules to the lower gland and to the conjunctiva and skin of the upper eyelid at the lateral angle of the eye. In addition it gives off a delicate branch which anastomoses with the zygomatic nerve of the second branch of the trigeminus.

3. The **nasociliary nerve** (Figs. 546, 547, 682, and 683) at first courses along the lateral side of the optic nerve, then crosses it obliquely, and runs between it and the superior rectus. It then passes through the medial portion of the orbit, lying close to the ophthalmic artery, across which it passes obliquely, and between the superior oblique and the medial rectus muscles it divides into its two terminals. The nerve ramifies in the orbit, especially in the eyeball, which it supplies with sensory nerves, and in the nasal cavity. Its branches are:

(*a*) The *long root of the ciliary ganglion* (Figs. 546 and 683) is a delicate, frequently double nerve filament which arises from the first part of the nerve, where it crosses the optic nerve. It represents the sensory root of the ciliary ganglion.

(*b*) The *long ciliary nerves* (Fig. 546) are usually several delicate threads which pass along the superior surface of the optic nerve to the eyeball and may divide before entering it (see Sense Organs).

(*c*) The *posterior ethmoidal nerve* (Figs. 546 and 547) accompanies the corresponding artery into the posterior ethmoidal cells and the sphenoidal sinus, whose mucous membrane it supplies. It arises from the portion of the trunk lying at the medial side of the orbit.

(*d*) The *anterior ethmoidal nerve* (Figs. 546 and 547) is much larger than the preceding one. It leaves the stem of the nasociliary nerve at a right angle and passes through the anterior ethmoidal foramen to the surface of the cribriform plate of the ethmoid, and, accompanied by the corresponding artery, it sinks through one of the anterior foramina of the plate into the nasal cavity, where it courses along the posterior surface of the nasal bone in a groove bearing its name. A few of its branches pass to the external skin of the nose and the majority to the nasal mucous membrane, the former being called the *external* (Fig. 592) and the latter the *internal nasal rami*, the internal rami being also known as the *anterior nasal rami* (Figs. 544 and 545), in contrast to the posterior nasal rami coming from the second division of the trigeminus. They ramify in the anterior part of the lateral nasal wall, as the *anterior lateral nasal nerves*, as well as in the anterior part of the nasal septum, these latter rami being known as the *anterior medial nasal nerves*. The external nasal ramus passes through the nasal bone or under its inferior border (between the bone and cartilage) to the external skin of the nose.

(*e*) The small, thin *infratrochlear nerve* (Figs. 541, 542, 547, 591, 592, 691, and 692) is the real terminal branch of the nasociliary nerve. With the terminal branch of the ophthalmic artery it passes beneath the trochlea of the superior oblique, anastomoses with the supratrochlear, and is divided into a smaller, *superior palpebral ramus*, which, in company with the latter nerve, goes to the upper eyelid, and a larger *inferior palpebral ramus*, which supplies the lower eyelid, the lachrymal gland, and the conjunctiva, as well as the bridge of the nose.

THE CILIARY GANGLION.

In the orbit there is a small, flat, round, or often three- or four-cornered gray ganglion about 2 or 3 mm. in size; it is the *ciliary ganglion* (Figs. 546 and 682). It lies in the fatty tissue of

the posterior portion of the orbit, lateral and close to the optic nerve, medial to the abducens, and a little superior to the inferior ramus of the oculomotor nerve. Like the optic nerve itself, it is covered by the superior rectus, the levator palpebræ superioris, and the superior ramus of the oculomotor, so that it lies fairly deeply in the orbital cavity. Usually it has a somewhat elongated form, branches from its anterior end passing to the eyeball, and its roots entering at its posterior end. It has three roots, a motor, a sensory, and a sympathetic. The motor root is formed by the *short root* of the ganglion from the oculomotor nerve; it is the largest of the roots and enters at the posterior inferior angle of the ganglion, furnishing the motor fibers for the innervation of the muscles of the interior of the eyeball. The sensory root is the *long root* and arises from the nasociliary nerve; it is weaker than the preceding, and enters the ganglion at the posterior superior angle. Together with it or close to it, several sympathetic nerve fibers from the internal carotid plexus, which first course along the ophthalmic artery, enter the posterior border of the ganglion, forming its sympathetic root or roots.

The branches which leave the ganglion at the anterior border are known as the *short ciliary nerves*. They course with the long ciliary nerves along the optic nerve, lying partly beneath and partly on the lateral and superior surfaces of the nerve, to the posterior border of the eyeball, which they enter by piercing the sclera. They are mixed nerves in contrast to the purely sensory, long ciliary nerves.

THE SECOND DIVISION OR MAXILLARY NERVE.

The second division of the trigeminal is the *maxillary nerve* (Figs. 684, 687, and 689). It is a little larger than the ophthalmic and is a flattened, oval, at first somewhat plexiform nerve, which passes through the foramen rotundum after becoming almost circular in outline, and so reaches the pterygopalatine (sphenomaxillary) fossa, where it divides into two main branches. The continuation of the trunk is the *infra-orbital nerve*, which passes almost in a straight course to the face, while the remaining portions, the *sphenopalatine nerves*, enter the sphenopalatine ganglion as its main sensory root, and thence pass to the palate and nasal cavity. Still another slender branch, the *meningeal nerve (middle)*, passes from the trunk of the nerve into the cranial cavity, and in the middle cranial fossa anastomoses with the spinous nerve of the third division (Figs. 679 and 682).

I. THE INFRA-ORBITAL NERVE.*

The infra-orbital nerve (Figs. 684, 686, and 689) is a strong, purely sensory nerve, which passes from the pterygopalatine (sphenomaxillary) fossa through the inferior orbital (spheno-maxillary) fissure into the orbital cavity, and then, following the course of the infra-orbital sulcus and canal, ramifies on the face.

Its branches are:

1. The **zygomatic nerve** (Figs. 689, 691, and 692) leaves the trunk as a rather weak branch in or even in front of the inferior orbital fissure, and, passing through the fissure, courses along its lateral wall to the *zygomatico-orbital foramen*, where it anastomoses with the anastomotic ramus of the lachrymal nerve. Passing through the zygomatico-facial canal of the zygomatic (malar) bone, it emerges upon the face as the *zygomatico-facial ramus* and is distributed to the

* By some authors the nerve is termed infra-orbital only after it has entered the orbit.

upper part of the cheek and the neighboring part of the lower eyelid, and also as the *zygomatico-temporal ramus* it passes through the zygomatico-temporal canal of zygomatic (malar) bone, then through the temporal fascia, often divided into several branches, to the skin of the anterior part of the temporal region and the lateral half of the forehead.

2. The **superior alveolar nerves** are divided into three groups:

(*a*) The *posterior superior alveolar nerves* (Figs. 543, 687, and 689) are given off from the trunk of the infra-orbital nerve while it is still in the pterygopalatine fossa, and go through the alveolar foramina of the tuberosity of the maxilla into the corresponding canals, so reaching the roots of the upper molar teeth. With the following groups they form the superior dental plexus.

(*b*) The middle group consists of the *middle superior alveolar nerve* (Fig. 689), which arises from the trunk in the infra-orbital canal and passes through a separate, small, bony canal in the wall of the maxillary sinus to the roots of the middle teeth and to the superior dental plexus.

(*c*) The *anterior superior alveolar rami* (Fig. 689) form the anterior group. They do not leave the trunk until it has reached the anterior portion of the infraorbital canal, and they course in the anterior wall of the maxillary sinus to the superior dental plexus.

The *superior dental plexus* (Fig. 689), which is formed by the superior alveolar nerves, lies between the two thin, bony lamellæ which bound the maxillary sinus above the roots of the teeth. It is formed by anastomoses of slender nerve filaments, which give rise to coarser upper and finer lower loops, lying on the roots of the teeth. Usually, also, a small branch passes to the plexus from the sphenopalatine ganglion. From the superior dental plexus arise, first, the *superior dental rami*, which pass to the various roots of the teeth of the upper jaw; second, the *superior gingival rami*, which supply the gums, piercing partly the alveolar septa and partly the anterior surface of the maxilla; third, branches to the maxillary sinus; and fourth, branches from the anterior part of the plexus to the lower nasal passage in the region of the incisive canal and to the inner surface of the ala of the nose (*internal nasal rami*). From the posterior superior alveolar nerves several branches pass directly to the posterior part of the upper gum and to the neighboring part of the buccal mucous membrane.

3. The terminal branch of the infra-orbital nerve (Figs. 541 to 543, 591, 592, 687, 691, and 692) passes through the infra-orbital foramen, under cover of the quadratus labii superioris and divides immediately into a number of diverging branches. The *inferior palpebral rami* pass to the lower eyelid and anastomose with branches of the zygomatico-facial and infratrochlear nerves; the *external nasal rami* pass to the skin of the middle part of the nose and anastomose with the external nasal ramus of the anterior ethmoidal nerve; and the *superior labial rami* pass to the skin and mucous membrane of the upper lip.

II. THE SPHENOPALATINE GANGLION.

The *sphenopalatine ganglion* (Figs. 684 to 686, and 689) is a rounded, triangular ganglion lying in the pterygopalatine fossa close to the sphenopalatine foramen. It is suspended loosely from the trunk of the maxillary nerve by the (second and third) *sphenopalatine nerves*, which form its sensory root. In addition to this main root it receives a second, the *nerve of the pterygoid canal* (Vidian nerve), which passes through the corresponding canal of the pterygoid process of the

FIG. 685.—The nerves and vessels of the nose. (Deep layer, the sphenopalatine ganglion.)

Dissection as in Fig. 545. In addition the pterygopalatine and pterygoid canals have been opened, the pyramid of the temporal bone sawn obliquely, and the tongue removed. * = Pterygoideus internus.

FIG. 686.—The otic and sphenopalatine ganglia.

Dissection as in Fig. 685. In addition the greater portion of the body of the sphenoid has been removed, the oval and palatine foramina opened, the temporal bone sawn away at the jugular foramen, the pterygoideus internus divided, and the soft palate cut away. + (White upon the middle meningeal artery) = the lesser superficial petrosal branch divided close to the ganglion.

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sphenoid, and really consists of two nerves usually very closely united in their course through the canal, one of which is the motor, the other the sympathetic root of the ganglion. The motor part of the nerve is the *greater superficial petrosal nerve*, a branch of the geniculate ganglion (page 205) of the facial nerve. It courses through the groove named after it in the anterior surface of the pyramid of the temporal bone, then through the sphenopetrosal fissure (or foramen lacerum), and then it crosses the internal carotid artery and enters the posterior aperture of the pterygoid canal. The second component of the nerve is the sympathetic root of the ganglion and is known as the *deep petrosal nerve*. It arises from the internal carotid plexus and passes from the foramen lacerum to the pterygoid canal, in which it unites with the preceding to form the nerve of the pterygoid canal.

The branches of the sphenopalatine ganglion are:

1. Small *orbital rami* to the orbit, which enter through the inferior orbital fissure and supply the smooth musculature of the orbit and the periorbita. A longer branch unites with the posterior ethmoidal nerve and helps in the supply of the mucous membrane of the sphenoidal sinus.

2. To the nasal cavity:

(*a*) The *posterior superior lateral nasal rami* (Figs. 544 and 545) enter through the spheno-palatine foramen and pass to the mucous membrane of the superior nasal meatus and of the superior and middle nasal conchæ and also to that of the sphenoidal sinus and of the posterior ethmoidal cells. A few delicate fibers also pass posteriorly to the uppermost portion of the pharyngo-nasal cavity.

(*b*) The *posterior superior medial nasal rami* (Fig. 544) also enter through the sphenopalatine foramen and ramify in the mucous membrane of the posterior part of the nasal septum. A longer branch, known as the *nasopalatine* (*Scarpa's*) *nerve* passes obliquely across the nasal septum from above and behind, downward and anteriorly, to the incisive canal, into which it sends some slender filaments which anastomose with the corresponding nerve of the other side and also with the terminals of the anterior palatine (see below) and superior alveolar nerves, forming with them a small plexus through which it takes part in the innervation of the pulp of the upper incisors.

(*c*) The *posterior inferior nasal rami* (Figs. 544 and 545), which supply the posterior part of the lateral wall of the nose, do not enter through the sphenopalatine foramen, but course with the palatine nerves for a short distance in the pterygopalatine canal. They leave this canal at the middle of its length through a lateral opening, and ramify in the middle and especially the inferior nasal conchæ and in the middle and inferior meatuses, and also in the mucous membrane of the maxillary sinus. Its branches also anastomose with the superior dental plexus.

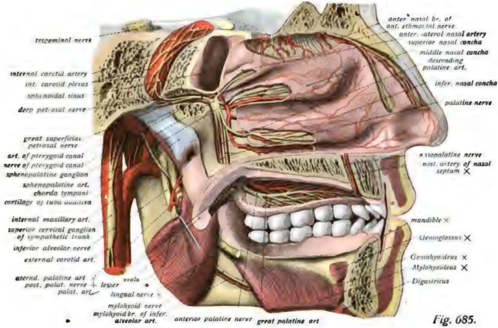


Fig. 685.

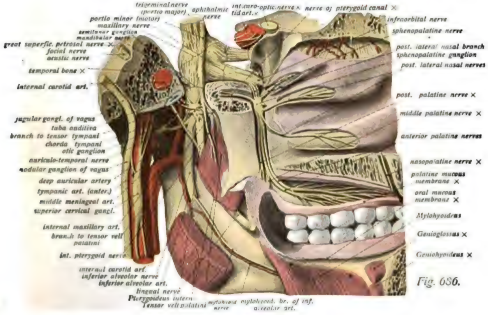


Fig. 686.

3. To the palate. The branches from the sphenopalatine ganglion going to the palate pass along with the descending palatine artery through the pterygopalatine canal. In this they divide into several branches, invested by a common sheath, these making their exit from the canal through the palatine foramina. These branches are:

(*a*) The ***anterior palatine nerve***, the strongest of the set, which passes through the anterior palatine foramen and ramifies with the greater palatine artery in the mucous membrane of the hard palate, reaching the incisive canal, where it anastomoses with the nasopalatine nerve (see above).

(*b*) The ***middle palatine nerve*** is much weaker than the preceding and passes through one of the minor palatine foramina; it ramifies in the mucous membrane above the palatine tonsil and partly in the velum of the palate.

(*c*) The ***posterior palatine nerve*** also passes through one of the small palatine foramina and in the palatine velum ramifies not only in the mucous membrane, but also in the levator veli palatini and musc. uvulæ. It, therefore, contains motor fibers for the muscles, which are supposed to enter the nerve by way of the great superficial petrosal, originating, that is to say, from the facial.

THE THIRD DIVISION OR MANDIBULAR NERVE.

The ***mandibular nerve*** (Figs. 543, 592, 684, 686, and 687) is the only one of the three divisions of the trigeminus which contains motor fibers from its origin onward, since the motor portio minor becomes associated with the sensory portio major as it comes from the semilunar ganglion. In the foramen ovale through which it leaves the cranial cavity, both parts, sensory and motor, blend to form a single nerve stem, which is the largest of the three trigeminal branches and preserves its reticular character long after leaving the semilunar ganglion. Shortly after its exit from the foramen, the third division, just as the other two, gives off a fine branch to the dura mater, the ***spinous nerve***, which enters the cranium with the middle meningeal artery through the foramen spinosum. It is a recurrent nerve (the inframaxillary recurrent nerve of Arnold), and anastomoses in the middle cranial fossa with the meningeal nerve from the second division.

The Otic Ganglion.—Just below the foramen ovale, at and attached to the medial side of the mandibular nerve, a small, elongated ganglion, the *otic ganglion* (Fig. 686), occurs. Frequently it has a plexiform character, being only poorly defined, and is connected with the trunk of the mandibular nerve as well as with several of its branches. The rami which pass from the trunk of the mandibular nerve to the otic ganglion are regarded as forming its motor root, while the sensory root is represented by the *lesser superficial petrosal nerve*. This is really the continuation of the tympanic nerve from the glossopharyngeal (see page 207), and enters the cranium by the superior aperture of the tympanic canaliculus, passes through the sulcus of the small superficial petrosal, then past the semilunar ganglion to the sphenopetrosal fissure; through this or a foramen in the wing of the sphenoid near the foramen spinosum (the foramen innominatum) the nerve passes to the posterior portion of the otic ganglion. In addition to this, sympathetic branches from the plexus of the middle meningeal artery (sympathetic root) pass to the ganglion, forming its sympathetic root.

The otic ganglion is connected not only with the trunk of the mandibular nerve, but also very intimately with the internal pterygoid, the auriculo-temporal, the spinous, and the chorda tympani

FIG. 687.—The nerves and vessels of the face (deepest or sixth layer, the mandibular nerve).

The dissection is the same as in Fig. 543, except that the mandibular condyloid process has been dislocated and the right half of the mandible almost entirely removed. The lower half of the buccinator has also been cut away. View from the side and from below. * – Posterior auricular nerve from facial. ** – Nerves to external auditory meatus from auriculo-temporal. · – Digastric branch of facial nerve. + + – Divided mylohyoideus. + + (Upon the artery) – cut surface of internal maxillary artery. • – Stump of sternocleidomastoid artery.

nerves. Delicate fibers pass even to the sphenopalatine and semilunar ganglia (the medial and lateral sphenoidal nerves). From the otic ganglion there arise, in addition to the connections with the internal pterygoid nerve, two small motor branches:

1. The *nerve to the tensor veli palatini* (Fig. 686), passing from the anterior border of the ganglion to the muscle bearing the same name.

2. The *nerve to the tensor tympani*, passing from the posterior part of the ganglion into the musculotubar canal to the muscle from which it takes its name.

Below the foramen ovale and the otic ganglion the mandibular nerve divides into its two main parts, a larger posterior sensory part, the principal portion of which forms the direct continuation of the trunk, and a smaller, anterior, motor part, which is a very short, reticular stem, the masticator nerve.

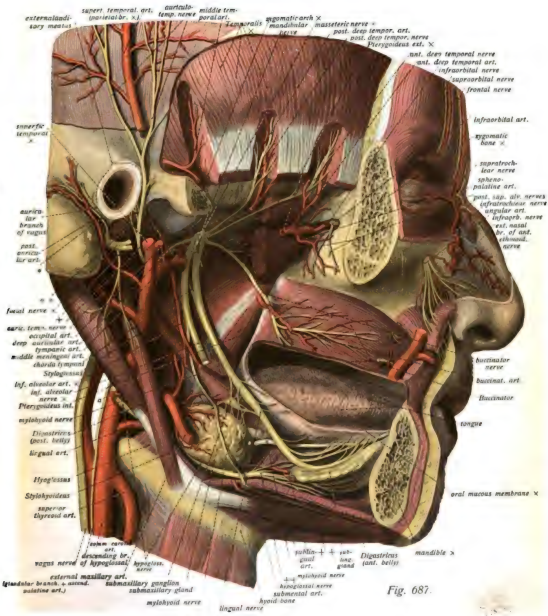
I. THE MASTICATOR NERVE.

All of the motor fibers of the mandibular nerve are not found united in the masticator nerve, for, in the first place, the nerves for the tensor veli palatini and tensor tympani come from the otic ganglion itself (apparently?), and, secondly, the motor mylohyoid nerve courses for a short distance along with the inferior alveolar nerve. On the other hand, it contains a sensory branch, the buccinator, whose origin is very closely related to the nerves supplying the muscles of mastication. The masticator nerve is divided almost immediately after its origin from the mandibular nerve into the following branches:

1. The *masseteric nerve* (Figs. 543 and 591) passes along the posterior border of the temporal muscle over the external pterygoid, laterally, to the sinus of the mandible and to medial surface of the masseter muscle. A fine, sensory branch passes from it to the temporomaxillary articulation.

2. The *deep temporal nerves* (Figs. 543 and 687), branches to the temporal muscle, are divided into the *anterior* and *posterior deep temporal nerves*. At first they pass rather obliquely, almost horizontally, between the muscle and squamous portion of the temporal bone, and then, accompanying the arteries, almost vertically upward over the great wing of the sphenoid, to innervate the temporal muscle.

3. The purely sensory *buccinator nerve* (Figs. 592 and 687) is the strongest and also the only sensory branch of the masticator nerve. It usually arises with the temporal and external pterygoid nerves and passes between the heads of the external pterygoid, then between that muscle and the temporal, and further on, lying between the masseter and buccinator, it courses laterally and downward to the buccinator, which it pierces at several places to reach the buccal mucous membrane. A small number of branches goes to the skin of the cheek near the corner of the mouth. It does not take part in the innervation of the buccinator muscle, which is supplied by the facial nerve.



externalaudi-tory meatus
supert. temporal. art. (parietal br. ×).
auriculo-temp. nerve
middle tem-poral art.
Temporalis ×
zygomatic arch ×
mandibular nerve
masseteric nerve
post. deep tempor. art.
post. deep tempor. nerve
Pterygoideus ext. ×
ant. deep temporal nerve
ant. deep temporal art.
infraorbital nerve
supraorbital nerve
frontal nerve
infraorbital art.
zygomatic bone ×
supratroch-lear nerve
spheno-palatine art.
post. sup. alv. nerves
infratrochlear nerve
angular art.
infraorb. nerve
ext. nasal br. of ant. ethmoid. nerve
buccinator nerve
buccinat. art
Buccinator
tongue
oral mucous membrane ×
mandible ×
Digastricus (ant. belly)
sub-ling. gland
sublin-gual art.
+ +
mylohyoid nerve
++ hypoglossal nerve
submental art.
hyoid bone
lingual nerve
mylohyoid nerve
submaxillary gland
submaxillary ganglion
external maxillary art. (glandular branch. + ascend. palatine art.)
hypogloss. nerve
comm carotid art.
descending br. of hypoglossal
vagus nerve
superior thyreoid art.
Stylohyoideus
Hyoglossus
lingual art.
Digastricus (post. belly)
mylohyoid nerve
Pterygoideus int.
inf. alveolar nerve ×
inf. alveolar art. ×
a
Styloglossus
chorda tympani
middle meningeal art.
tympanic art.
deep auricular art.
occipital art.
auric. temp. nerve
+
facial nerve ×
× ×
post. auricu-lar art.
auricu-lar branch of vagus
superfic. temporal ×

Fig. 687.

4. The *internal pterygoid nerve* (Fig. 686) does not always appear as an independent nerve, but is especially closely connected to the otic ganglion (see above). It supplies the internal pterygoid muscle, and often the fibers which go to the tensor veli palatini pass for a short distance closely united with it.

5. The *external pterygoid nerve* (Figs. 686 and 687) is often given off as several branches from the buccinator in which it may be enclosed. It passes to the external pterygoid muscle.

II. THE POSTERIOR SENSORY PORTION OF THE MANDIBULAR NERVE.

The posterior sensory or main portion of the mandibular nerve continues in the direction of the trunk, but soon divides into three branches, the auriculotemporal, and the two real terminal rami, the lingual and alveolar nerves, which are the strongest branches.

1. The **auriculotemporal nerve** (Figs. 541, 543, 591, 592, 686, 687, 691, and 692) arises from the mandibular nerve usually by two roots which embrace the middle meningeal artery, and it has also connecting rami from the otic ganglion. It passes at first posteriorly along the median surface of the temporomandibular articular capsule and then courses upward to the anterior surface of the external auditory canal, lying between the external and internal carotid arteries and surrounded by the lobules of the parotid gland. It is at first deeply situated, but gradually curves toward the surface, so that finally it comes to lie beside the superficial temporal artery between the tragus of the external ear and the root of the zygomatic arch, beneath the temporal fascia in which its terminal branches ramify. Its branches are:

(*a*) The *nerves of the external auditory meatus*, two and three in number, are small rami which enter the auditory canal between its cartilaginous and bony portions and supply its mucous membrane. One branch, the *ramus to the tympanic membrane*, reaches the tympanic membrane.

(*b*) The *parotid branches* pass to the parotid gland.

(*c*) *Anastomosing branches to the facial nerve* accompany the branches of the facial nerve and take part in the innervation of the skin of the face.

(*d*) The *anterior auricular branches* pass to the skin of the lateral surface of the pinna near the tragus.

(*e*) The real terminal branches are the *superficial temporal rami*. These course behind the superficial temporal artery up to the skin of the temples, where they anastomose with the supraorbital, zygomaticotemporal, and greater occipital nerves.

2. The **lingual nerve** (Figs. 543, 544, 588, 685 to 687, and 695), the sensory nerve of the tongue and the anterior terminal branch of the main sensory portion of the mandibular nerve, separates from the posterior terminal or inferior alveolar nerve just below the point where the auriculotemporal is given off, but remains in close proximity to it for some distance. Both nerves pass between the external and internal pterygoid muscles, medial to the internal maxillary artery, and in this situation the lingual nerve is joined at an acute angle by the *chorda tympani*, which passes from above downward from the petrotympanic fissure and is a branch of the facial (intermediate) nerve (see page 205). The lingual then separates more and more from the inferior alveolar by curving slightly forward and downward to the lateral border of the tongue.

The **submaxillary ganglion** (Fig. 687) is connected to the trunk of the lingual nerve by several fibers and is a flat, somewhat triangular ganglion, about 2 mm. in length, and lies above

the submaxillary gland on the lateral (inferior) surface of the hyoglossus muscle. Its roots are (1) branches from the lingual nerve, which are really fibers from the chorda tympani,* and (2) sympathetic branches from the neighboring external maxillary plexus. The branches passing from the ganglion are (1) the *submaxillary rami*, which go to the submaxillary gland and extend along the submaxillary duct to the sublingual glands, and (2) *communicating branches to the lingual nerve*, which pass into the peripheral part of that nerve, and in this way probably reach the sublingual glands.

Before the lingual nerve forms the submaxillary ganglion it gives off—

(*a*) Delicate *rami to the isthmus of the fauces*, supplying the mucous membrane of the fauces, (*b*) small anastomosing *rami to the hypoglossal nerve*, (*c*) the *sublingual nerve* to the sublingual glands and the mucosa of the floor of the mouth cavity, and (*d*) the terminal branches, the *lingual rami* (Fig. 695), which pass to the mucosa of the tongue. They consist of several branches which penetrate the musculature of the lateral border of the tongue in a fan-like manner and ramify in the mucosa of the dorsal surface of the organ from the tip to the vallate papillæ.

3. The *inferior alveolar nerve* (Figs. 543, 591, 592, 691, and 692), the second terminal branch of the sensory main part of the mandibular, passes behind the lingual nerve along the lateral side of the internal pterygoid, to the mandibular foramen. Before its main trunk enters the mandibular canal it gives off—

(*a*) The purely motor *mylohyoid nerve* (Figs. 539, 543, 551, 685 to 687, and 700) which courses as a long but comparatively thin nerve in company with the corresponding arterial branch through the mylohyoid sulcus of the mandible, lying at first between the internal pterygoid and the ramus of the mandible, then along the lateral surface of the styloglossus, and further on between the anterior lateral border of the submaxillary gland and the mandible. Finally, it curves around the posterior border of the mylohyoid to the inferior surface of that muscle, where, accompanying the submental artery, it supplies the mylohyoid muscle and also the anterior belly of the digastric.

(*b*) The main stem of the inferior alveolar passes in company with its artery through the mandibular canal, lying at first in front of and then medial to the artery, and forms the *inferior dental plexus*, which consists of a fine network of nerve filaments and gives rise to the *inferior dental* and *inferior gingival rami* supplying the teeth and gums.

(*c*) The *mental nerve* is the remaining portion of the inferior alveolar which does not pass into the dental plexus. It leaves the mandibular canal through the dental foramen and divides under cover of the triangularis and quadratus labii inferioris into numerous branches, which pass as *mental rami* to the skin of the chin and as *inferior labial rami* to the mucous membrane and skin of the lower lip.

THE SEVENTH CEREBRAL OR FACIAL NERVE.

The *facial nerve* (Figs. 541, 542, 591, 691, 692, 684, and 688 to 690) emerges between the posterior border of the pons and the upper end of the olive from the uppermost part of the medulla and is purely motor at its origin. In the internal acoustic meatus, through which it

* The chorda tympani is the continuation of the intermediate nerve. In addition to it the mandibular nerve receives fibers from the glossopharyngeal through the lesser superficial petrosal, these probably being gustatory fibers.

leaves the cranium, it receives the *intermediate nerve*, which has its origin close to it in the brain. Lying in the facial canal it traverses the petrous portion of the temporal bone, and after its exit from this it begins its real ramification. It is the motor nerve of almost all muscles of the head except those of mastication and the muscles of the tongue.

1. At the first bend of the canal below the hiatus (see Vol. I, page 43) a small triangular ganglion, the *geniculate ganglion* (Figs. 684, and 688 to 690) occurs in the course of the nerve, formed by the intermediate nerve (see page 187), which from this point onward courses with the facial nerve. Since the facial nerve, as well as the canal, makes a rectangular bend at the ganglion, this point is termed the (external)* *geniculum of the facial nerve* (Figs. 801 to 804). From the ganglion arises the greater superficial petrosal nerve, which passes to the spheno-palatine ganglion as described above. Probably this nerve contains fibers passing not only from the facial to the maxillary nerve, but also reversely, and thus carries sensory fibers from the trigeminal to (the peripheral part of) the facial; it forms, therefore, a mutual anastomosis. Also arising from the geniculate ganglion there is an *anastomotic ramus to the tympanic plexus* (see page 207).

2. During its further course through the facial canal, shortly after passing the prominence, the facial nerve gives off a *stapedial branch* which passes to the corresponding muscle of the auditory apparatus.

3. Also, in the vertical terminal portion of the canal, the *chorda tympani* (Figs. 684, 686 to 688, 690, 803, and 804), that is to say, the peripheral end of the sensory intermediate nerve, is given off. This is a long, thin nerve which passes through its canal obliquely upward to the tympanic cavity, which it enters through the tympanic aperture of the canal for the chorda tympani. In the cavity it passes between the short process of the incus and the neck of the malleus (see Sense Organs), and, with the anterior ligament of the malleus, leaves the tympanic cavity through the petrotympanic fissure. Then, as described above (see page 203), it joins the lingual nerve, which it leaves partly at the submaxillary ganglion and partly in the trunk of the sublingual nerve.

After its exit from the facial canal the facial nerve describes an arch, convex inferiorly, around the external acoustic meatus, and traverses the substance of the parotid gland in which it branches extensively, forming the *parotid plexus*. Before forming this plexus it sends off a few smaller branches:

4. The *posterior auricular nerve* (Figs. 541, 542, 591, and 697) arises just below the stylomastoid foramen and passes behind the ear and along the anterior border of the mastoid process to the posterior auricular muscle, also supplying the transverse and oblique auricular and the antitragicus muscles. Its terminal branch, the *occipital ramus*, passes to the occipital muscle.

5. The *digastric branch* (Fig. 591) arises just below the preceding and supplies the posterior belly of the digastric, and by the *stylohyoid ramus* the neighboring stylohyoid muscle.

6. The *anastomotic ramus to the glossopharyngeal nerve* is a fine branch, which often pierces the stylohyoid, and passes to the ninth cerebral nerve.

7. The **parotid plexus** (Figs. 541, 542, 691, and 692) is formed in the substance of the parotid gland by looped anastomoses of the separate branches of the facial. It is completely imbedded in the parotid gland, but lies much nearer to its medial than to its lateral surface. The

* The internal genu of the facial nerve is in the rhomboidal fossa (see page 175).

FIG. 689.—The second branch of the trigeminal nerve, the sphenopalatine ganglion, the intracranial portion of the facial nerve, and the tympanic nerve.

The orbit has been opened by a sagittal section through its outer portion, its contents removed, the pterygoid canal opened, and the temporal bone sawn obliquely, exposing the tympanum and the facial canal. * = External pterygoid plate. ** = Infra-orbital nerve with the overlying zygomatic nerve. † = Carotico-tympanic nerve. *† = Anastomosis between great superficial petrosal and tympanic nerves. + + = Anastomosis between facial and tympanic nerves.

FIG. 690.—The intracranial portion of the facial nerve.

The facial canal has been opened and the tympanum exposed from behind.

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facial nerve usually enters the gland by two strong branches, which ramify among the lobules and are connected with one another by loops, thus producing a wide-meshed network. From this plexus a varying number of rami, partly large and partly small, diverge anteriorly, superiorly, and inferiorly to innervate the muscles of the face proper and the platysma. These branches anastomose with neighboring sensory branches, especially with those of the trigeminus, in such a way that the branches of the trigeminus may carry motor fibers of the seventh, and the latter, sensory fibers of the fifth to the neighboring muscles or portions of the skin or mucosa.

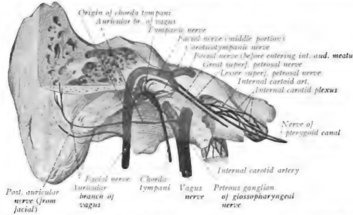

FIG. 688.—The intracranial course of the facial nerve and its communications schematically introduced into Fig. 4 (Vol. I).

From the parotid plexus of the facial the following branches, enumerated from below upward, arise:

(*a*) The ***ramus colli*** (Figs. 691, 692, 698, and 699) appears at the anterior border of the parotid gland and passes through the submaxillary region and carotid fossa to the medial surface of the platysma. It forms a constant anastomosis with the cutaneous cervical nerve (see page 214).

(*b*) The ***marginal mandibular ramus*** appears above the preceding between the lobules of the gland, and is often double. It courses parallel to the base of the mandible (covered by the platysma) to the chin, and ramifies in the triangularis, quadratus labii inferioris, and mentalis muscles.

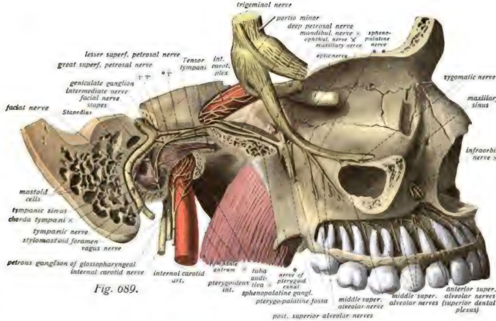

Fig. 689.

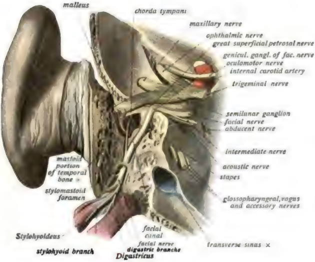

Fig. 690.

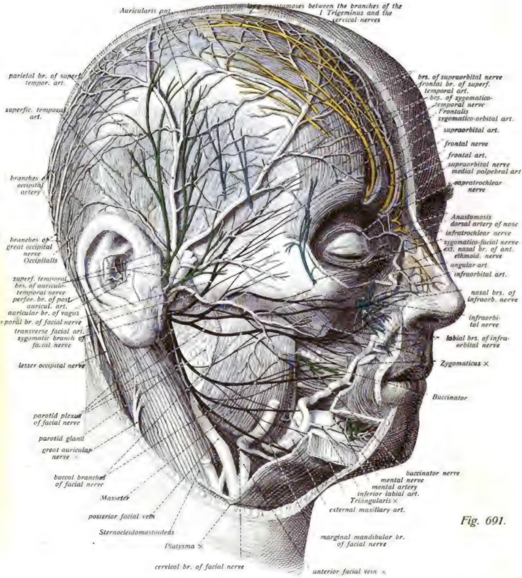

Fig. 691.

Fig. 691 and 692. Superficial nerves and arteries of the face, deeper layer. Most of the parotid gland is removed. The facial muscles have been cut away, divided, or drawn downwards. The colors of the nerves are the same as in Fig. 541.

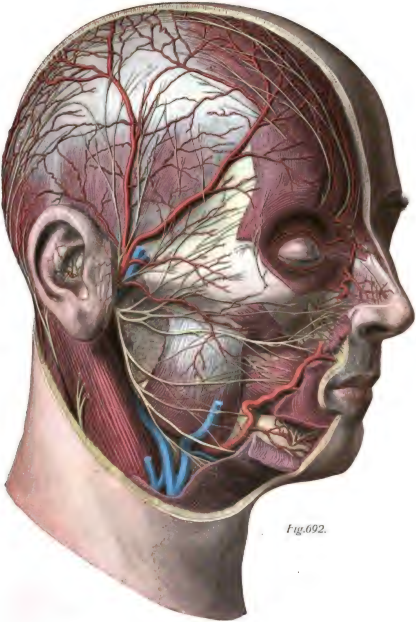

Fig. 692.

(*c*) The ***buccal rami***, two to five in number, pass transversely across the lateral surface of the masseter, partly near the parotid duct, and ramify mainly in the buccinator, zygomaticus, and quadratus labii superioris, caninus, orbicularis oris, and nasalis muscles.

(*d*) The ***zygomatic rami***, two to three in number, pass parallel to the zygomatic arch, in company with the transverse facial artery, to the orbicularis oris, and partly also to the zygomaticus and quadratus labii superioris.

(*e*) The ***temporal rami*** appear in the form of two or three medium-sized rami at the superior border of the parotid gland and innervate the anterior and superior auricularis, the small muscles of the lateral face of the pinna, the orbicularis oculi, and the frontalis.

THE NINTH AND TENTH CEREBRAL NERVES, THE GLOSSOPHARYNGEUS AND VAGUS.

The glossopharyngeus and vagus are closely related in several respects, for they arise together from common nuclei in the medulla oblongata (page 187) and they leave the medulla together at the lateral border of the olive, a separation of their roots before they reach the jugular foramen being often impossible. Both are mixed nerves, they innervate a common region and both are visceral nerves.

THE GLOSSOPHARYNGEAL NERVE.

The ninth cerebral nerve or *glossopharyngeus* (Fig. 693), while still in the region of the jugular foramen, forms a ganglionic enlargement, the *superior ganglion* of the glossopharyngeal, and after its exit from the cranium, after receiving a sympathetic branch from the superior cervical ganglion, it forms the small round *petrosal ganglion*, lying in the petrosal fossa of the temporal bone. From this ganglion one of the most important branches has its origin:

1. The *tympanic nerve* (Figs. 688 to 690 and 693) passes from the petrosal fossa through the tympanic canal into the tympanic cavity, and ramifies on its medial wall, especially on the promontory, in the form of the *tympanic plexus* (Jacobson's) plexus. In this region the branches of the tympanic nerve communicate with the anastomosing ramus of the facial and with two branches of the internal carotid plexus, the superior and inferior caroticotympanic nerves, which enter the tympanic cavity through similarly named canals. From this plexus arises, in addition to numerous fine branches for the tympanic mucosa and a *tubal ramus* for the mucosa of the tuba auditiva, the *lesser superficial petrosal nerve*, which leaves the tympanic cavity through the superior tympanic canaliculus and passes to the otic ganglion (page 201).

From the petrosal ganglion branches also pass to the trunk of the vagus and a fine ramus passes deeply into the jugular fossa to anastomose with the auricular branch of the vagus.

The trunk of the glossopharyngeus below the petrosal ganglion lies at first close to the vagus and then diverges from it to come to lie upon the medial surface of the stylopharyngeus muscle. It then lies in front of the jugular vein and passes between the internal and external carotid arteries to the lateral wall of the pharynx. At the insertion of the stylopharyngeus it bends forward and laterally, and, with the styloglossus, reaches the lateral border of the tongue, where its terminal ramification takes place. The other branches of the glossopharyngeal are:

2. The ***stylopharyngeal ramus***, which innervates the muscle of the same name.

3. The ***pharyngeal rami*** (Fig. 693), several branches to the pharyngeal plexus in whose formation vagus and sympathetic fibres also have a part.

FIG. 693.—The nerves and vessels of the posterior and external walls of the pharynx.

Upon the right side are shown the veins and the arteries; upon the left side only the nerves and some of the arteries. The posterior portion of the skull has been removed by a section passing through the jugular foramina. The sympathetic nerves are shown only upon the right side.

4. The ***tonsillar rami*** to the palatine tonsil.

5. The *lingual rami* (Figs. 544, 545, 694), the true terminals, pass to the root of the tongue, especially to the lingual follicles and between them, by numerous fine branches, to the vallate papillæ. They carry taste fibers from the taste buds and also supply the anterior surface of the epiglottis.

THE TENTH CEREBRAL OR VAGUS NERVE.

The *vagus nerve* (Figs. 538, 539, 551, 693, and 700) derives its name from its extraordinarily long course, being the only cranial nerve that reaches the abdominal cavity, and, with the sympathetic system, it represents the principal visceral nerve. It leaves the medulla together with the glossopharyngeus, forms the small *jugular ganglion* in the jugular foramen, and communicates with the glossopharyngeal and the sympathetic nerve. Below the jugular foramen the large nerve trunk lies behind the glossopharyngeus, but in front of the internal jugular vein and spinal accessory nerve, and in this region it communicates not only with the glossopharyngeus, but also with the hypoglossal nerve, and receives the so-called internal branch of the spinal accessory (see below). Strengthened by this and with the aid of a large sympathetic nerve, the jugular nerve (see below), the vagus forms at the level of the transverse processes of the first and second cervical vertebræ, the reticular *ganglion nodosum* (nodosal plexus). This is almost 2 cm. long and lies in the groove between the internal carotid artery and the internal jugular vein. The nerve passes down the neck between and behind these two vessels, below the hyoid bone, between the common carotid artery and internal jugular vein, and close to the sympathetic trunk.

At its entrance into the thoracic cavity the nerve has these same relations. On the left side it then passes downward with the common carotid artery lying laterally to it and in front of the left subclavian artery, to the arch of the aorta, over which it passes; on the right side it follows down the lateral side of the innominate artery and passes in front of the right subclavian artery, but behind the ascending aorta. In the thoracic cavity each nerve comes to lie behind the corresponding innominate vein and passes behind the bronchus of its side to form the pulmonary plexus, and then, descending along the œsophagus, the right vagus somewhat posterior and the left anterior to it, it passes through the diaphragm to the stomach, where it terminates by forming the gastric plexus.

In its course the vagus may be divided into four portions:

1. The cranial portion, 2. The cervical portion, 3. The thoracic portion, and 4. The abdominal portion.

The **cranial portion** has only unimportant branches:

1. The *meningeal ramus*, a small, very fine branch, which passes from the nerve as it lies in the jugular foramen to the dura mater of the posterior cranial fossa.

2. The *auricular ramus* (Figs. 541 to 543, 591, 592, and 691 to 693), a slender but very long

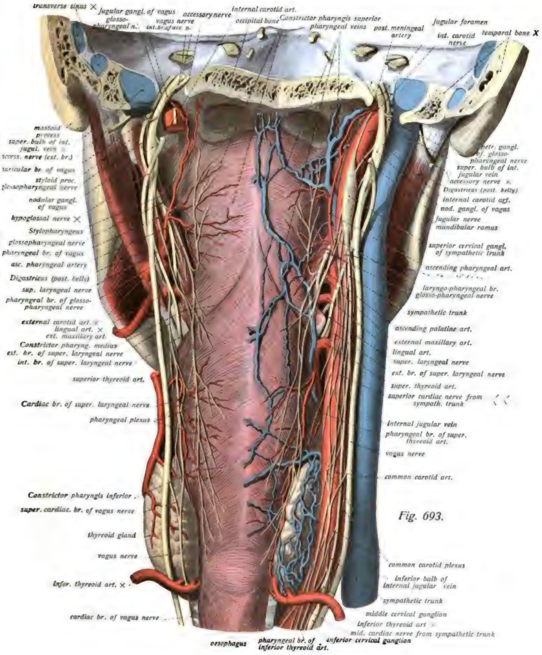
transverse sinus ×
Jugular gangl. of vagus
glosso-pharyngeal n.
vagus nerve
int. br. of acc. n.
accessory nerve
internal carotid art.
occipital bone
Constrictor pharyngis superior
pharyngeal veins
post. meningeal artery
jugular foramen
int. carotid nerve
temporal bone ×
mastoid process
super. bulb of int. jugul. vein
ccess. nerve (ext. br.)
uricular br. of vagus
styloid proc.
lossopharyngeal nerve
nodular gangl. of vagus
hypoglossal nerve ×
Stylopharyngeus
glossopharyngeal nerve
pharyngeal br. of vagus
asc. pharyngeal artery
Digastricus (post. belly)
sup. laryngeal nerve
pharyngeal br. of glosso-pharyngeal nerve
external carotid art. ×
lingual art. ×
ext. maxillary art.
Constrictor pharyng. medius
ext. br. of super. laryngeal nerve
int. br. of super. laryngeal nerve
superior thyreoid art.
Cardiac br. of super. laryngeal nerve
pharyngeal plexus
Constrictor pharyngis inferior
super. cardiac. br. of vagus nerve
thyreoid gland
vagus nerve
infer. thyreoid art. ×
cardiac br. of vagus nerve
oesophagus
pharyngeal br. of inferior thyreoid art.
inferior cervical ganglion
petr. gangl. of glosso-pharyngeal nerve
super. bulb of int. jugular vein
accessory nerve ×
Digastricus (post. belly)
internal carotid art.
nod. gangl. of vagus
jugular nerve
mandibular ramus
superior cervical gangl. of sympathetic trunk
ascending pharyngeal art.
laryngo-pharyngeal br. glosso-pharyngeal nerve
sympathetic trunk
ascending palatine art.
external maxillary art.
lingual art.
super. laryngeal nerve
ext. br. of super. laryngeal nerve
super. thyreoid art.
superior cardiac nerve from sympath. trunk
internal jugular vein
pharyngeal br. of super. thyreoid art.
vagus nerve
common carotid art.
common carotid plexus
inferior bulb of internal jugular vein
sympathetic trunk
middle cervical ganglion
inferior thyreoid art
mid. cardiac nerve from sympathetic trunk

Fig. 693.

nerve, which is somewhat peculiar in its relations. It arises from the jugular ganglion and passes at first into the jugular fossa, and then enters the mastoid canaliculus (see Vol. I, page 56), in which it courses and anastomoses with the facial nerve. It then enters the external acoustic meatus through the tympanomastoid fissure and ramifies in the posterior wall of the cartilaginous portion, and in the skin of the concha of the ear. It is the only sensory branch on the face which arises from a cerebral nerve other than the trigeminal.

The **cervical portion** is characterized by possessing the nodose ganglion and by forming numerous connections with almost all the neighboring nerves. Notwithstanding its long course in the neck it sends out branches from the nodose ganglion only, and from this only a single large nerve, the superior laryngeal. The remaining part, below the ganglion, usually has no branches. The branches of the cervical portion are:

1. An *anastomotic ramus to the glossopharyngeus* (Fig. 693).

2. The *pharyngeal rami* (Fig. 693), several fine rami coming from the ganglion nodosum, which course along the internal carotid artery to the lateral and posterior walls of the pharynx, where they communicate with the corresponding branches of the glossopharyngeal (page 207) and sympathetic nerves to form the pharyngeal plexus. From this the pharyngeal constrictors are supplied, as well as the mucosa of the pharnyx. A fine branch extends to the levator veli palatini.

3. The *superior cardiac rami* (Fig. 693), long slender branches which arise partly from the ganglion nodosum and partly from the trunk of the following nerve, and pass downward along the common carotid artery to the cardiac plexus (see below).

4. The *superior laryngeal nerve* (Figs. 539, 693, and 694), the only large branch of the cervical region, arises from the lower end of the ganglion nodosum. It passes medial to and behind the internal and external carotid arteries and descends obliquely and medial to the lateral wall of the oral portion of the pharnyx, where it divides into a larger internal and a smaller external branch.

(*a*) The *external branch* usually anastomoses at its origin with a superior cardiac ramus* and often also with the pharyngeal plexus. It courses downward along the origins of the thyreopharyngeus muscle and ramifies in that muscle and in the cricothyreoideus, so that it is essentially a motor nerve.

(*b*) The much larger *internal branch* is purely sensory. Running along with the superior laryngeal artery it pierces the hyothyreoid membrane, then passes in the fold for the laryngeal nerve in the pyriform recess (Vol. II, page 42) to the entrance to the larynx, supplying the posterior surface of the epiglottis, the entrance of the larynx itself, and the pharyngeal mucosa surrounding it, as well as the mucous membrane of the larynx as far down as the vocal cords. Furthermore, behind the lateral portion of the posterior crico-arytenoid muscle it anastomoses with the inferior laryngeal nerve (see below).

The **thoracic portion** of the vagus gives off the recurrent laryngeal nerve and also rami

* In many animals, the rabbit for example, a special nerve arises from the superior laryngeal or vagus, which, on account of its physiological function, is [illegible]d the *depressor nerve*. In man it does not occur as an independent nerve, but its fibers are included in the vagus [illegible]s an afferent nerve, carrying impulses from the heart to the medulla oblongata, where they are transferred to the v[illegible]otor centers and produce dilatation of the intestinal vessels and thereby a diminution of the blood-pressure.—Ed.

FIG. 694.—The nerves and arteries of the larynx and of the base of the tongue as seen from behind.

The mucous membrane has been removed from the anterior pharyngeal wall and also from the tongue along the glossopharyngeal nerve.

FIG. 695.—The nerves and arteries of the tongue and of the larynx as seen from below and in front.

The veins are also shown upon the left side of the tongue; the right hyoglossus has been divided.

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for the heart and lung, and it has strong anastomoses with the superior thoracic sympathetic ganglion. Its branches are:

1. The *recurrent nerve* (Figs. 538, 551, 694, and 726), the largest of all the branches of the vagus, differs in its origin on the right and left sides. On the left it arises more deeply and surrounds the lower and posterior surfaces of the arch of the aorta in a wide curve; on the right it lies somewhat higher, just below the superior thoracic aperture, and forms a gentle curve around the root of the right subclavian artery. Thus the right recurrent passes behind the right subclavian artery and the left behind the arch of the aorta, after which both have a common course. Lying behind the corresponding common carotid arteries they leave the superior thoracic aperture and pass upward upon the lateral surface of the trachea, in the groove between it and the œsophagus. In this groove the nerve passes behind the thyreoid gland up to the larnyx, to which it is distributed. Its branches are:

(*a*) The *inferior cardiac rami* to the cardiac plexus; these often arise independently from the thoracic portion of the vagus.

(*b*) The *tracheal rami* to the cervical portion of the trachea.

(*c*) The *œsophageal rami* to the cervical portion of the œsophagus.

(*d*) The actual terminal branch, the *inferior laryngeal nerve* (Fig. 694) pierces the crico-pharyngeus, which it supplies, and comes to lie on the lateral surface of the inferior portion of the larynx, where it connects with an anastomosing branch from the superior laryngeal nerve and divides into an anterior and a posterior ramus. The *anterior ramus* supplies the lateral crico-arytenoid, the thyreo-arytenoid, and the vocal muscles; the *posterior*, the posterior crico-arytenoid and the muscles of the laryngeal opening. The inferior laryngeal nerve thus supplies all muscles of the larynx with the exception of the cricothyreoid, which is innervated by the external ramus of the superior laryngeal, and in addition it carries sensory fibers to the lower half of the larynx.

Both laryngeal nerves, the superior as well as the inferior, arise from the vagus, but their origins are a long distance apart, the superior arising in the upper part of the neck and the inferior in the thorax.

2. The *anterior* and *posterior bronchial rami* (Figs. 538 and 726) are numerous and in part very strong branches of the vagus, which pass along the bronchi to the hilus of the lung, the posterior ones being the longer. In the hilus they form the weaker *anterior pulmonary plexus* and the stronger *posterior pulmonary plexus*, the latter being strengthened by branches from the thoracic portion of the sympathetic system; both plexuses send branches along the bronchial rami into the lung. The trachea also receives branches from the anterior bronchial rami at its bifurcation.

After giving off the bronchial rami the trunk of the vagus becomes decidedly weaker and continues its course along the œsophagus no longer in the form of a single nerve, but as

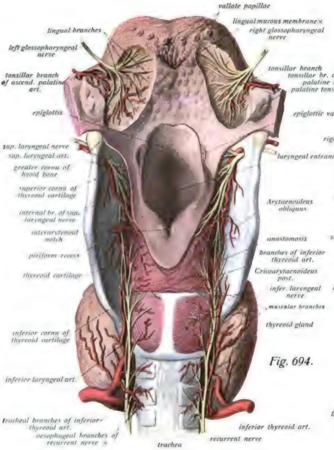


Fig. 694.

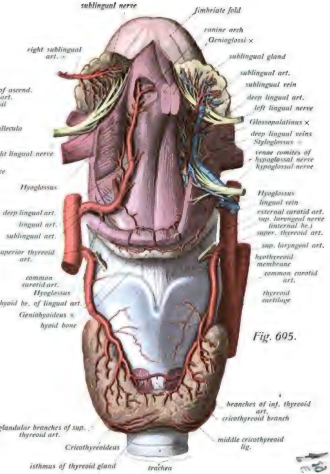


Fig. 695.

several anastomosing stems termed the *anterior* and *posterior œsophageal chords;* the continuation of the left vagus is upon the anterior surface, that of the right, along the posterior surface of the œsophagus. By the anastomoses of the separate stems and by the branches which they send to the thoracic portion of the œsophagus, the smaller *anterior* and larger *posterior œsophageal plexuses* arise.

The **abdominal portion** of the vagus consists of its terminal ramification at the stomach (Fig. 726). These form frequent anastomoses with the sympathetic plexuses of the abdomen and, together with sympathetic nerves, extend to almost all the abdominal * viscera. The branches are named as follows:

1. The *anterior* and *posterior gastric plexuses* are the direct continuations of the œsophageal plexus upon the stomach wall and anastomose with the superior gastric sympathetic plexus (see below). They give off—

(*a*) *Gastric rami* to the stomach itself.
(*b*) *Hepatic rami* to the liver.
(*c*) *Cœliac rami* to the cœliac plexus.
(*d*) *Splenic rami* to the spleen.
(*e*) *Renal rami* to the kidneys.

THE ELEVENTH CEREBRAL OR ACCESSORY NERVE.

The *accessory nerve* (Figs. 539, 551, 693, and 697 to 700) is a purely motor nerve, only a part of whose root fibers arise from the brain (medulla oblongata), the inferior ones having their origin in the cervical portion of the spinal cord (see page 187) and, even in the upper part of the vertebral canal, forming a nerve stem, which becomes larger above as it ascends parallel with the spinal cord and with it enters the cranium through the foramen magnum. Here it lies on the lateral surface of the medulla and receives additional roots from its lateral funiculus, and finally leaves the cranium through the jugular foramen. Directly after its exit, while lying in close proximity to the vagus, the nerve divides into an *internal ramus*, which blends with the vagus just below the jugular foramen, and an *external ramus*, the larger portion, composed mainly of the spinal fibers. The external ramus passes in front of the internal jugular vein and then backward, downward, and laterally to the medial surface of the upper third of the sternocleidomastoid muscle, after having previously made several anastomoses with the cervical nerves. Then the accessory nerve, for so the external branch is frequently termed for brevity's sake, usually pierces the muscle or emerges from under its posterior border and passes obliquely backward and downward through the supraclavicular fossa, receiving constant anastomoses from branches of the cervical plexus. Thus strengthened, it courses to the anterior border and surface of the trapezius, which it supplies.

THE TWELFTH CEREBRAL NERVE OR HYPOGLOSSUS.

The motor nerve of the tongue (Figs. 539, 551, 588, 593, 693, 695, and 700) is the *hypoglossus*. It belongs to the purely motor cerebral nerves and arises by a number of root fibers from the ventral surface of the medulla oblongata, between the pyramid and the olive. It leaves the

* The vagus fibers take part in the formation of the myenteric plexus of the wall of the small intestine, and perhaps they even extend to the large intestine.

cranial cavity, through the hypoglossal canal as an almost round stem, surrounded by a venous plexus (the rete of the hypoglossal canal, see page 87). At first it lies medial to the vagus and posterior to it, and also behind the internal jugular vein, with which it passes horizontally downward; then it curves around the medial side of the internal jugular and runs between it and the lateral surface of the internal carotid artery, to pass forward and medially, lying at first between the branches of the external carotid artery and the digastric muscle. Further on it crosses the tendon of the digastric, and, passing under cover of the common facial vein and the submaxillary gland, comes to lie upon the superior border of the greater cornu of the hyoid bone. On the lateral surface of the hyoglossus muscle, above the mylohyoid, and separated from the lingual artery by the hyoglossus, the nerve passes almost horizontally forward to the tongue, the sternocleidomastoid artery winding around it at the curved middle part of its course. In its upper vertical portion the hypoglossus anastomoses with the ganglion nodosum of the vagus, and also with the superior cervical ganglion of the sympathetic and with the superior branches of the cervical plexus, in this manner receiving motor branches from the cervical plexus, with which it innervates the infrahyoid muscles, while the fibers originally belonging to the nerve pass to the muscles of the tongue*). The branches of the hypoglossus are:

1. The *descending ramus* (Figs. 539, 551, and 700), the longest of its branches, comes from the posterior part of the curved middle portion of its course and really consists of fibers which have passed to the hypoglossus from the cervical plexus (see above). It passes downward through the carotid fossa, lying closely upon the anterior lateral surface of the common carotid artery and enclosed in a common sheath with it, to below the omohyoid muscle. It gives muscular branches to both bellies of the omohyoid and to the sternohyoid and sternothyreoid muscles. More rarely it gives off fibers, which join it through its anastomosis of the vagus, to the cardiac plexus, and it forms constantly an anastomosis with the cervical nerves, which is sometimes double and is known as the ansa hypoglossi (see page 215).

2. The *thyreohyoid ramus* from the hypoglossus arises at the greater cornu of the hyoid, and, like the preceding ramus, consists of fibers from the cervical plexus which have joined the hypoglossus through its anastomosis. It is a slender branch which passes to the muscle bearing the same name.

The terminal branching of the hypoglossus into the *lingual rami* (Figs. 544, 588, and 695) takes place in the floor of the mouth, above the mylohyoid muscle. Here the nerve, accompanied by a vein (vena comitans of the hypoglossal, page 89), divides into a number of branches, which anastomose partly with one another and partly also with those of the more lateral lingual nerve (page 204), and pass to the geniohyoid and the remaining true muscles of the tongue.

The Spinal Nerves.

The spinal nerves may be divided, as has already been indicated (page 121), into cervical, thoracic, lumbar, sacral, and coccygeal nerves.

* Sensory fibers also join the hypoglossus through these anastomoses and are carried by it to its area of distribution.

THE CERVICAL NERVES.

Eight pairs of *cervical nerves* (Figs. 539, 551, 696 to 702, and 714) are usually recognized, the two nerves which leave the spinal canal between occiput and atlas being counted as the first pair and those that emerge through the intervertebral foramen between the seventh cervical and first thoracic vertebra being regarded as the last pair. While the posterior divisions of the cervical nerves have no important anastomoses with one another, the anterior divisions of the first to the fourth unite to form the cervical plexus, and those of the fifth to the eighth form the much larger brachial plexus. In contrast to what occurs in other spinal nerves the posterior rami of the upper two cervical nerves, especially of the first, are larger than the anterior ones.

THE POSTERIOR RAMI OF THE CERVICAL NERVES.

The posterior rami of the cervical nerves are united in front of the semispinalis capitis by anastomoses which seem to be most constant in the upper nerves. Each ramus divides into a *medial* and a *lateral ramus*, which pass both to the muscles and to the skin of the neck. From the exceptionally large posterior rami of the two upper nerves are formed two nerves having special names:

1. The *suboccipital nerve* (Fig. 696) is the (larger) posterior branch of the first cervical nerve and is almost purely motor, since this nerve has only a very weak posterior (sensory) root.* Along with the vertebral artery it enters the deep triangle of the neck formed by the rectus capitis posterior major, the obliquus capitis superior, and the obliquus capitis inferior, and supplies these muscles as well as the rectus minor, the rectus lateralis, and the semispinalis capitis. Sensory branches pass to the atlanto-occipital articulation.

2. The *great occipital nerve* (Figs. 551, 696, 699, and 714), the large posterior branch of the second cervical, is for the most part sensory. It communicates constantly with the posterior division of the third cervical † after curving around the inferior border of the obliquus capitis inferior, and branches beneath the semispinalis capitis, sending muscular branches to this muscle and to the multifidus cervicis and the neighboring deep muscles of the neck. The sensory main portion of the nerve pierces the semispinalis capitis and the superior part of the trapezius, and passes close to the external occipital protuberance, along the medial side of the occipital artery to the skin of the occiput, sending some long, slender branches to the vertex and anastomosing with branches of the occipitalis minor, the auriculotemporal, and the supra-orbital nerves.

THE ANTERIOR RAMI OF THE CERVICAL NERVES.

The anterior rami of the cervical nerves pierce the intertransversarii muscles and then appear as large flat cords at the lateral border of the longus colli and rectus capitis anterior in the deeper parts of the neck. After receiving communicating rami from the cervical and upper thoracic ganglia of the sympathetic trunk, they form arched anastomoses with one another, the cervical ansæ, and these are usually succeeded in the lower cervical nerves by several more acute-angled anastomoses. The upper four cervical ansæ form the cervical plexus, the lower four, together with the largest part of the first thoracic nerve, form the brachial plexus.

* The first cervical nerve thus resembles the hypoglossus, whose posterior root is entirely wanting in man.

† Sometimes this branch of the third cervical is independent and forms the *third occipital nerve* lying medial to the occipitalis major.

FIG. 696.—The deep layer of the nerves and vessels of the nuchal region.

The semispinales capitis have been reflected and the deep nuchal triangle exposed. Upon the right side the veins have been left and the trapezius reflected; upon the left the trapezius has been reflected and the rhomboidei divided.

* = Branch of dorsal scapular nerve to levator scapulæ. ** = Portion of the occipital vein which empties into the deep cervical vein. † = Communication between occipital and external jugular veins. † * = Communication between second and third cervical nerves (great occipital nerve).

FIG. 697.—The superficial nerves and vessels of the left side of the neck. (First layer of neck.)

The skin has been removed from the margin of the jaw to below the clavicle, as has also the superficial layer of the cervical (or nuchal) fascia behind the platysma. ** = An accessory cutaneous branch of the cervical plexus.

THE CERVICAL PLEXUS.

The *cervical plexus* (Figs. 539, 551, 697 to 700, and 702) is formed by the arched anastomoses of the anterior branches of the upper four cervical nerves. Since those of the two upper nerves are very weak, the most important branches of the plexus arise from the third and fourth nerves, and partly from the second. The plexus is covered by the sternocleidomastoid muscle and lies upon the origins of the levator scapulæ and the scalenus medius, behind the internal jugular vein. Beside giving off special branches the plexus makes communications with several of the cerebral nerves, as with the ganglion nodosum of the vagus, with the trunk of the hypoglossus (first cervical), and with the accessory nerve. Its branches are partly motor and partly sensory, the latter being the more important.

I. THE SENSORY BRANCHES OF THE CERVICAL PLEXUS.

1. The *lesser occipital nerve* (Figs. 541, 542, 591, 691, 692, and 697 to 700) arises principally from the second, but partly also from the third cervical nerve, and appears, usually only as a medium-sized nerve,* at the posterior border of the upper third of the sternocleidomastoid muscle. It courses along the posterior border of this muscle and over the mastoid process to the skin of the lateral occipital region. It anastomoses with the posterior branch of the following nerve and with the greater occipital nerve.

2. The *great auricular nerve* (Figs. 541, 542, and 697 to 699) is much larger than the preceding nerve, and arises mainly from the third cervical. It winds about the posterior border of the sternocleidomastoid, a little above the middle of the muscle, and then passes almost vertically upward over its lateral surface. It crosses the external jugular vein, at the lateral side of which it lies at first, and at a varying level divides into an anterior and a posterior branch. The *anterior ramus* traverses the parotid gland and ramifies in the skin of the lateral concave side of the pinna and also in that of the neighboring portion of the parotideomasseteric region. The *posterior ramus* passes up behind the ear and branches on the medial surface of the pinna, also anastomosing by means of perforating branches with the small occipital on the concave side of the pinna, as well as in the skin behind and above that structure.

3. The *cutaneous cervical nerve* (Figs. 697 and 698) arises from the third cervical together with the great auricular, and with it bends around the posterior border of the sternocleidomastoid and then passes forward horizontally over the lateral surface of the muscle. It is covered by the platysma, which it pierces by several branches; the upper ones, known as the *superior rami*,

* It is always, frequently decidedly, weaker than the greater occipital nerve.

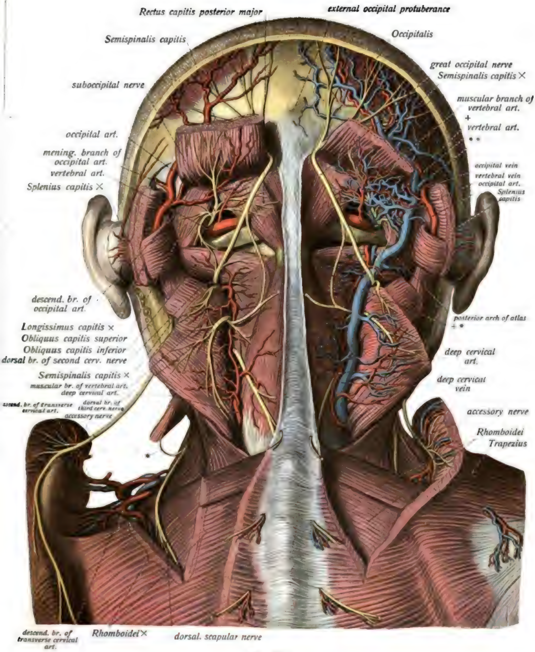
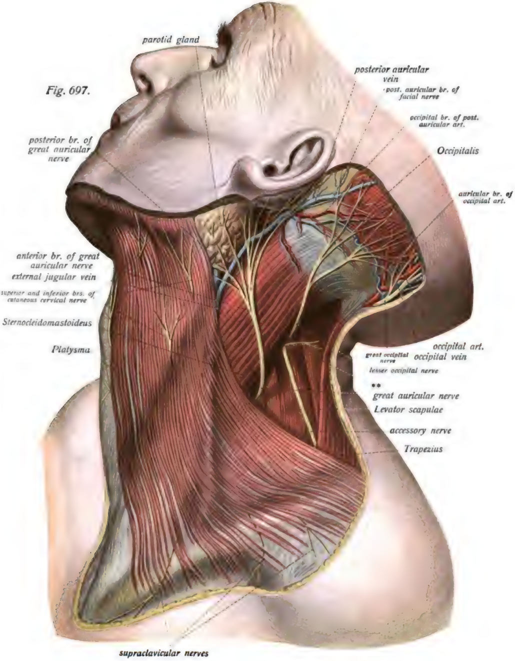

Rectus capitis posterior major
external occipital protuberance
Semispinalis capitis
Occipitalis
suboccipital nerve
great occipital nerve
Semispinalis capitis ×
muscular branch of vertebral art.
+
vertebral art.
* *
occipital art.
mening. branch of occipital art.
vertebral art.
Splenius capitis ×
occipital vein
vertebral vein
occipital art.
Splenius capitis
descend. br. of occipital art.
posterior arch of atlas
+ *
Longissimus capitis ×
Obliquus capitis superior
Obliquus capitis inferior
dorsal br. of second cerv. nerve
deep cervical art.
Semispinalis capitis ×
muscular br. of vertebral art.
deep cervical art.
deep cervical vein
ascend. br. of transverse cervical art.
dorsal br. of third cerv. nerve
accessory nerve
accessory nerve
Rhomboidei
Trapezius
*
descend. br. of transverse cervical art.
Rhomboidei ×
dorsal. scapular nerve

Fig. 696.

Fig. 697.


parotid gland
posterior auricular vein
post. auricular br. of facial nerve
occipital br. of post. auricular art.
Occipitalis
auricular br. of occipital art.
posterior br. of great auricular nerve
anterior br. of great auricular nerve
external jugular vein
superior and inferior brs. of cutaneous cervical nerve
Sternocleidomastoideus
Platysma
occipital art.
great occipital nerve
occipital vein
lesser occipital nerve
**
great auricular nerve
Levator scapulae
accessory nerve
Trapezius
supraclavicular nerves

anastomosing with the cervical branch of the facial (superficial cervical ansa) and ramifying in the skin of the neck up to the chin, while the *inferior rami* are distributed down to the clavicle.

4. The *supraclavicular nerves* (Figs. 595, 697, 699, and 710) arise mainly from the fourth cervical, appear at the posterior border of the sternocleidomastoid as two or three stems, and pass, covered at first by the platysma, transversely through the supraclavicular fossa. They then divide into a number of diverging branches, which pass superficially over the clavicle, the anterior branches passing over the sternoclavicular articulation, traverse the intervals between the diverging bundles of the platysma, and ramify as the *anterior supraclavicular nerves* in the upper portion of the skin of the thorax, as the *middle supraclavicular nerves* in the skin of the infraclavicular fossa, and as the *posterior supraclavicular nerves* in the skin of the shoulder (deltoid region).

II. MOTOR BRANCHES OF THE CERVICAL PLEXUS.

The majority of the motor branches of the cervical plexus are short branches for the intertransversarii muscles and the rectus capitis anterior and longus capitis, and also for the upper portion of the levator scapulæ. They also form anastomoses with the accessory nerve for the innervation of the (sternocleidomastoid and) trapezius. Only two of them require special notice.

1. The branch to the *ansa hypoglossi* (Figs. 539, 551, and 700). From the second and third cervical nerves branches arise which communicate with the descending ramus of the hypoglossus (see page 212) to form a loop, the *ansa hypoglossi*. They usually pass forward and downward in the form of a separate nerve trunk along the medial side of the sternocleidomastoid and cross the lateral surface of the internal jugular vein.

2. The *phrenic nerve* (Figs. 539, 700, and 701) is by far the most important and longest branch of the plexus. It arises mainly from the fourth cervical nerve, but partly also from the third and sometimes with a small root from the fifth, and very rarely even the sixth cervical nerves. It passes downward on the anterior surface of the scalenus anterior to its insertion and enters the superior thoracic aperture behind the sternoclavicular articulation and between the subclavian artery and vein. It then continues its course through the thorax, lying in front of the root of the lung, close to the pericardium, and covered by the pericardial pleura, in company with the pericardiacophrenic vessels, to the superior surface of the diaphragm. The right nerve pursues the straighter course, keeping close to the right innominate vein and the superior vena cava, and, lower down, resting on that portion of the pericardium which covers the wall of the right atrium. The left passes over the greatest curvature of the left ventricle and the apex of the heart. The left nerve enters the costal part of the diaphragm in the neighborhood of the apex of the heart, while the right one passes along the inferior vena cava and enters the diaphragm by several branches. Those branches which pierce the diaphragm, mainly in the foramen for the vena cava, but partly also in the œsophageal hiatus, and innervate the lumbar part are termed the *phrenico-abdominal branches*.

The phrenic nerve is not purely motor, but gives a sensory *pericardiac branch* to the pericardium, as well as delicate branches to the superior surface of the liver.

FIG. 698.—The superficial nerves and veins of the left side of the neck. (Second layer of neck.)

The platysma has been divided, the upper portion reflected toward the jaw, and the lower portion removed. The fascia has been divided along the facial veins. * = Anastomosis of accessory nerve with cervical plexus. + = Communication of external jugular vein with deep veins.

The upper perforating branches of the internal mammary vessels (not represented in the illustration) make their appearance between the origins of the sternocleidomastoideus.

FIG. 699.—The nerves, arteries, and veins of the left side of the neck. (Third layer of neck.)

The superficial layer of the cervical fascia and the superficial veins have been removed, exposing the superficial muscles. In the dissection from which the illustration was made, the superficial cervical artery was comparatively small and partly replaced by the ascending branch of the transverse cervical artery.

FIG. 700.—The nerves and vessels of the deeper layer of the left side of the neck. (Fourth layer of neck.)

The sternocleidomastoideus has been cut away, except at its origin and insertion, and the superficial veins have been removed, as have also the common facial and smaller veins. The branches of the cervical plexus have been cut away, except the lesser occipital, the phrenic, and muscular filaments. XX = Cross-section of external jugular vein near its termination. * = Cross-section of anterior jugular vein near its termination. X = Cross-section of common facial vein (near terminatio). * = Branch of cervical plexus to ansa hypoglossi. ** = Cross-section of superior thyreoid vein (termination). + = Sternocleidomastoid branch of superior thyreoid artery (divided).

THE BRACHIAL PLEXUS.

The *brachial plexus* (Figs. 539, 551, 552, 588, 699, 700, 702, and 703) is formed by the union of the very strong anterior branches of the fifth to the eighth cervical and the first thoracic nerves. These appear at the lateral border of the scalenus anterior, the fifth to seventh above the subclavian artery, the eighth behind it, and the first thoracic, which curves upward around the neck of the first rib, below the artery. The five strong, flattened nerve trunks unite in the space between the scaleni, lateral to the artery, and converge to form a reticular broad nerve cord between whose fasciculi the transversalis colli artery winds. Lying lateral to the subclavian artery the plexus passes behind the clavicle into the depth of the infraclavicular fossa and to the axillary fossa.

That portion of the plexus which lies above the clavicle is known as the supraclavicular portion. The nerves which arise from it are distributed to the thoracic and scapular regions, while the true brachial nerves arise from a rearrangement of the plexus which takes place in the axillary fossa. This latter part of the plexus is known as the infraclavicular portion.*

The Supraclavicular Part of the Brachial Plexus.—To the *supraclavicular portion* of the brachial plexus, the following six predominantly motor nerves are assigned, but all of them do not become independent above the clavicle. The first nerves which separate from the plexus are, in addition to the anterior thoracics, the suprascapular and dorsal scapular nerves.

1. The *dorsal scapular nerve* (Figs. 696 and 714) is purely motor, and arises from the fifth to the seventh cranial nerves. It frequently pierces the scalenus medius, which it may supply, and, in company with the descending branch of the transverse cervical artery, passes to the rhomboid muscle, in front of which it continues its course downward. In addition to supplying the rhomboids it also sends branches, as a rule, to the inferior part of the levator scapulæ.

2. The *long thoracic nerve* (Figs. 551, 552, and 594) is the motor nerve to the serratus anterior.

* This division is not altogether appropriate, since several of the nerves of the supraclavicular portion occasionally or regularly arise from the plexus below the level of the clavicle.

Fig. 698.

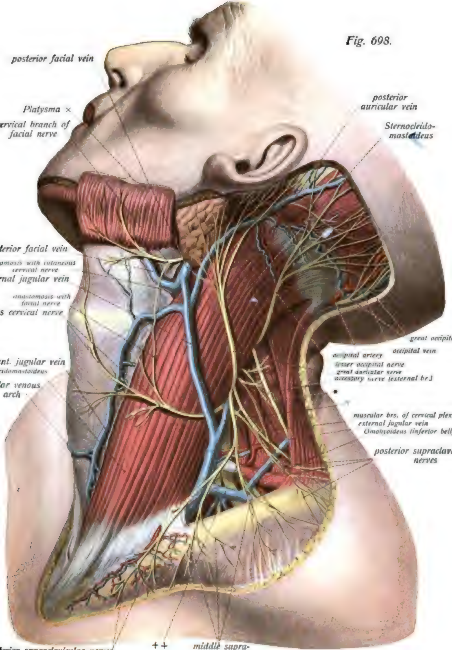

posterior facial vein
Platysma ×
cervical branch of facial nerve
anterior facial vein
anastomosis with cutaneous cervical nerve
external jugular vein
anastomosis with facial nerve
cutaneous cervical nerve
ant. jugular vein
Sternocleidomastoideus
jugular venous arch
posterior auricular vein
Sternocleidomastoideus
great occipital nerve
occipital vein
occipital artery
lesser occipital nerve
great auricular nerve
accessory nerve (external br.)
*
muscular brs. of cervical plexus
external jugular vein
Omohyoideus (inferior belly)
posterior supraclavicular nerves
anterior supraclavicular nerves
++
middle supraclavicular nerves

Fig. 699.

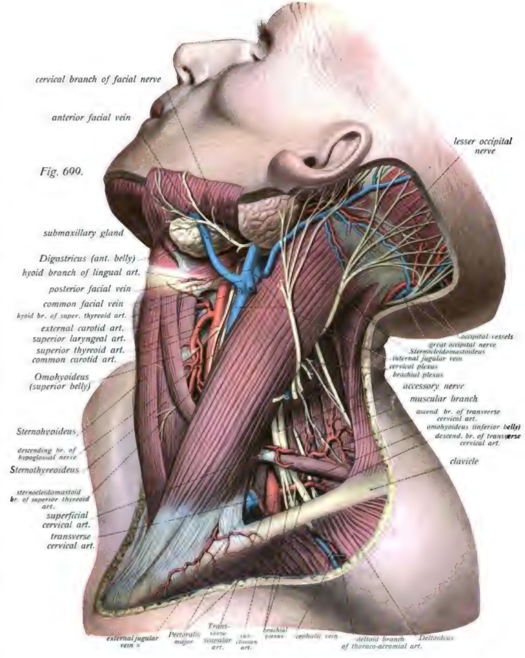
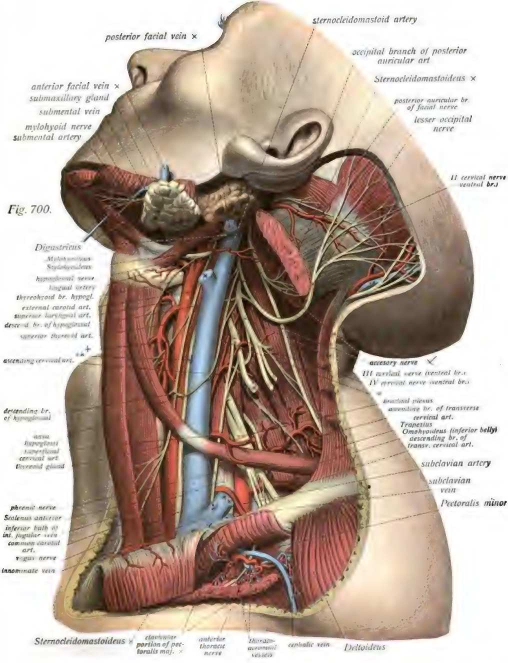

cervical branch of facial nerve
anterior facial vein
submaxillary gland
Digastricus (ant. belly)
hyoid branch of lingual art.
posterior facial vein
common facial vein
hyoid br. of super. thyreoid art.
external carotid art.
superior laryngeal art.
superior thyreoid art.
common carotid art.
Omohyoideus (superior belly)
Sternohyoideus
descending br. of hypoglossal nerve
Sternothyreoideus
sternocleidomastoid br. of superior thyreoid art.
superficial cervical art.
transverse cervical art.
lesser occipital nerve
occipital vessels
great occipital nerve
Sternocleidomastoideus
internal jugular vein
cervical plexus
brachial plexus
accessory nerve
muscular branch
ascend. br. of transverse cervical art.
omohyoideus (inferior belly)
descend. br. of transverse cervical art.
clavicle
external jugular vein ×
Pectoralis major
Transverse scapular art.
subclavian art.
brachial plexus
cephalic vein
deltoid branch of thoraco-acromial art.
Deltoideus

Fig. 700.


posterior facial vein ×
sternocleidomastoid artery
occipital branch of posterior auricular art
Sternocleidomastoideus ×
anterior facial vein ×
submaxillary gland
submental vein
mylohyoid nerve
submental artery
posterior auricular br. of facial nerve
lesser occipital nerve
II cervical nerve (ventral br.)
Digastricus
Mylohyoideus
Stylohyoideus
hypoglossal nerve
lingual artery
thyreohyoid br. hypogl.
external carotid art.
superior laryngeal art.
descend. br. of hypoglossal
superior thyreoid art.
++
+
ascending cervical art.
accesory nerve ✓
III cervical nerve (ventral br.)
IV cervical nerve (ventral br.)
brachial plexus
ascending br. of transverse cervical art.
Trapezius
Omohyoideus (inferior belly)
descending br. of transv. cervical art.
descending br. of hypoglossal
ansa hypoglossi
superficial cervical art
thyreoid gland
subclavian artery
subclavian vein
Pectoralis minor
phrenic nerve
Scalenus anterior
inferior bulb of int. jugular vein
common carotid art.
vagus nerve
innominate vein
Sternocleidomastoideus ×
clavicular portion of pectoralis maj. ×
anterior thoracic nerve
thoraco-acromial vessels
cephalic vein
Deltoideus

It also has its origin from the fifth to the seventh cervical nerves and passes down on the lateral surface of serratus anterior, a short distance behind the lateral thoracic artery.

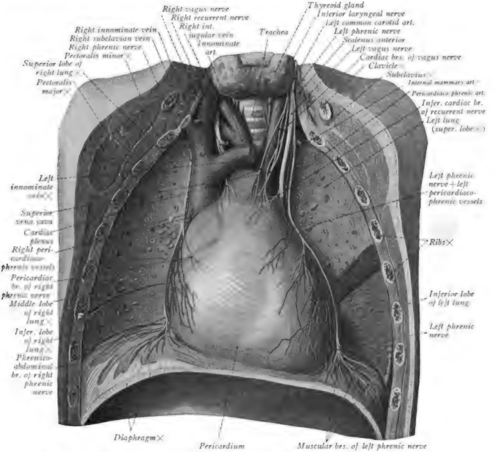


FIG. 701.—The course of the phrenic nerves through the thoracic cavity to the diaphragm.

Upon both sides the thoracic wall has been divided to the outer side of the nipple line. The right lung has been removed as far as the plane of the section and part of the left has been still further cut away. The pericardial pleuræ have been dissected from the pericardium to expose the phrenic nerves and pericardiacophrenic vessels. One half of the left innominate vein has been removed.

The dorsal scapular and long thoracic nerves are collectively spoken of as the ***posterior thoracic nerves***, in contrast to the following:

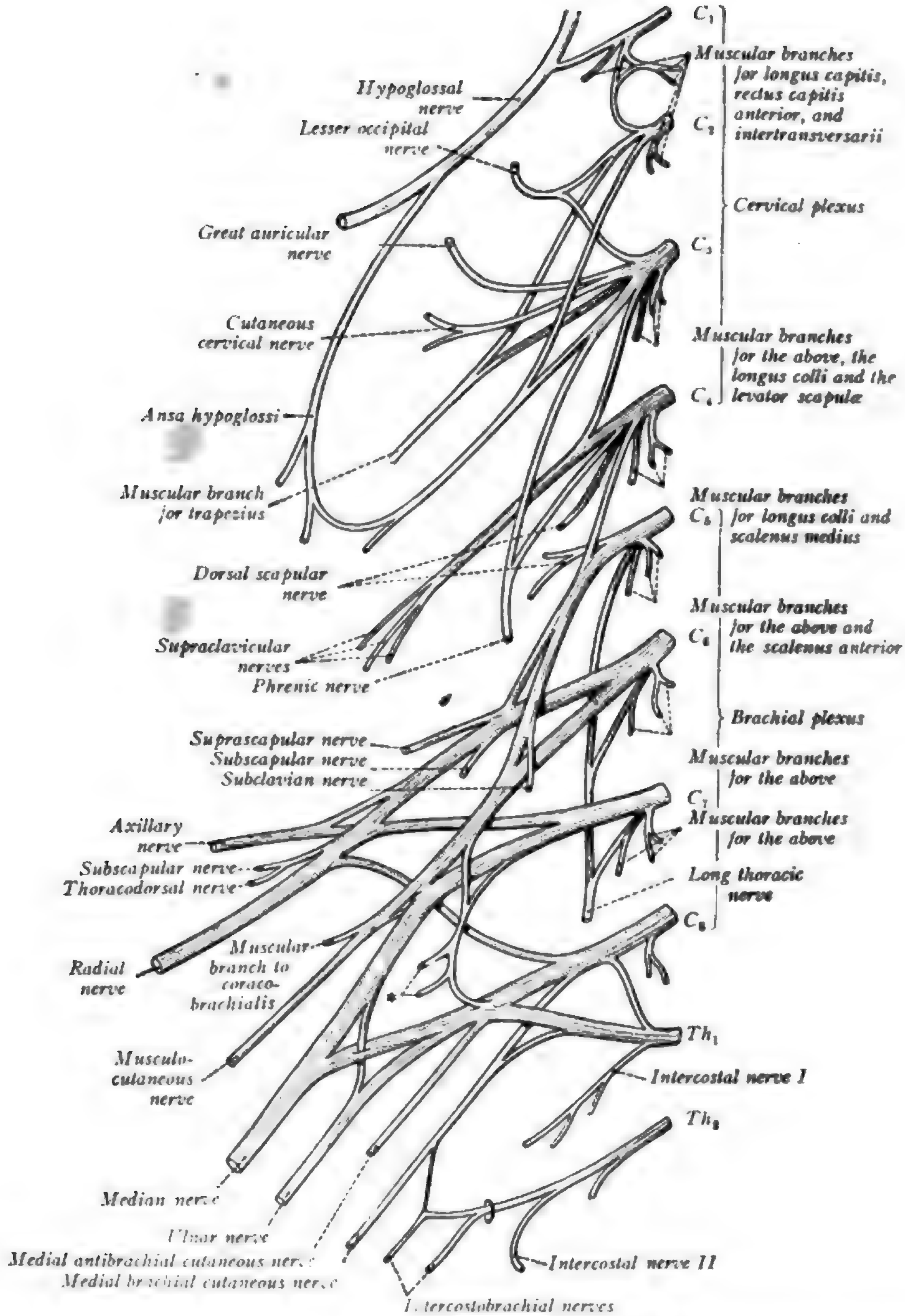


FIG. 702.—The plan of the cervical and brachial plexuses (after P. Eisler, somewhat simplified).
* = Anterior thoracic nerves.

3. The *anterior thoracic nerves* (Figs. 539, 551, and 700), also motor, have their origin from the fifth to the eighth cervical nerves. They are several nerves which arise above the clavicle and course behind it to the subclavius muscle (*subclavian nerve*), and then passing through the interval between this and the pectoralis minor are distributed to the latter muscle and to the pectoralis major.

4. The *suprascapular nerve* (Figs. 703 and 704), also almost exclusively motor, arises mainly from the sixth cervical, and is already independent in the supraclavicular fossa. Accompanying the transverse scapular artery it passes along the inferior belly of the omohyoid, behind the clavicle to the scapular notch, which it traverses, passing beneath the superior transverse scapular ligament and separated by it from the transverse scapular artery. It is distributed to the supraspinatus and infraspinatus muscle and also sends several fine branches to the capsule of the shoulder-joint.

5. The *subscapular nerves* (Figs. 552, 594, 703, and 704), also motor, arise from the sixth and seventh cervical nerves. They consist of two or three smaller and one stronger, larger branch; the former passes to the subscapularis and teres major muscle and the latter, known as the *thoraco-dorsal* (*long subscapular*) *nerve* goes with the corresponding artery to the latissimus dorsi.

6. The last branch, belonging to the supraclavicular portion of the plexus, is known as the *axillary* (*circumflex*) *nerve* (Figs. 556, 557, 594, 703, 704, and 710). It is assigned to this group of nerves principally on account of its distribution, for it is mainly a motor nerve to the muscles of the shoulder. But it is also the only one of the group that contains larger, sensory fibers, and it is not supraclavicular in origin, but arises in the axilla, together with the radial nerve, from the posterior cord of the brachial plexus (see below). Its fibers come mainly from the sixth and seventh cervical nerves and it passes with the posterior circumflex artery of the humerus through the quadrangular space between the teres major, teres minor, triceps, and humerus (see Vol. I, page 187), giving off *muscular rami* to the deltoid and teres minor. A sensory branch, the *lateral brachial cutaneous nerve* (Figs. 556 and 710), winds around the posterior border of the deltoid and ramifies in the skin which covers the inferior part of the muscle (adjoining the area of distribution of the posterior supraclavicular rami), and below the insertion of the deltoid.

The Infraclavicular Portion of the Brachial Plexus.—Below the clavicle, after the branches of the supraclavicular portion (with the exception of the axillary nerve) have been given off, a rearrangement of the constituents of the brachial plexus * takes place in the axillary fossa. The plexus in the upper portion of the axilla, lateral to the axillary artery, becomes arranged about the artery in the form of three fasciculi, so that a *lateral*, a *medial*, and a *posterior fasciculus* can be recognized. The lateral fasciculus is composed mainly of parts of the fifth, sixth, and seventh cervical nerves, the medial arises from the eighth cervical nerve and first thoracic (and, to a certain extent, also from the seventh cervical), and the posterior arises largely from the same constituents as the lateral, but receives also a few branches from the inferior nerve roots of the plexus.† These three cords give origin to the six nerve trunks of the infraclavicular part

* The infraclavicular part is also spoken of as the brachial plexus, in a narrower sense.

† [By this rearrangement the fibers intended for the posterior surface of the limb are separated from those destined for the anterior surface. The former are collected in the posterior fasciculus, which thus receives fibers from all the nerve roots of the plexus, while the latter are divided between the medial and lateral fasciculi.—ED.]

FIG. 703.—The nerves and vessels of the shoulder. (Anterior view.)
* = Long head of triceps.

FIG. 704.—The nerves and vessels of the shoulder. (Posterior view.)
The deltoid has been partly removed and the remainder reflected; a piece has been sawn out of the acromion; and the supraspinatus, infraspinatus, and teres minor have been divided and slightly retracted. * = Branch of axillary nerve to teres minor.

of the brachial plexus, and also to the axillary nerve. From the lateral fasciculus arise the musculocutaneous nerve and the lateral root of the median; from the medial fasciculus the medial root of the median nerve, the ulnar, the median brachial cutaneous, and the median antibrachial cutaneous; and from the posterior fasciculus the radial and axillary nerves.

The distribution of the axillary nerve has already been described. Of the remaining six nerves, three, the median, ulnar, and radial, are large stems which extend throughout the entire length of the extremity to the hand, while the other three are mainly cutaneous nerves, the musculocutaneous, however, having motor fibers in its proximal portion, while its distal part is sensory.

The Three Small Nerves of the Infraclavicular Portion.—1. The *musculocutaneous nerve* (Figs. 554, 555, 595, 596, 703, and 704) is the largest of these three nerves. It arises from the lateral fasciculus and contains fibers from the fifth, sixth, and seventh cervical nerves. It passes laterally to the coracobrachialis, which it pierces, as a rule, and then courses downward to the region of the elbow-joint between the biceps and the brachialis, supplying all three muscles.* From here on it is purely sensory and is called the *lateral (radial) antibrachial cutaneous nerve* (Figs. 554, 555, 595, and 596). This passes through the fascia at the lateral border of the tendon of the biceps and courses downward subcutaneously with the cephalic vein upon the lateral surface of the forearm, ramifying in the skin of the radial half of the volar surface and the radial border of the forearm. It extends to the radial side of the back of the hand where it anastomoses with the superficial ramus of the radial nerve.

2. The *medial brachial (lesser internal) cutaneous nerve* (Figs. 552, 594, 595, 703, and 711) is much weaker than the preceding and arises from the medial fasciculus, containing fibers from the eighth cervical and first thoracic nerves. In the axilla it unites with the lateral cutaneous branch of the second, and often also of the third intercostal nerves (*intercostobrachial anastomosis*) and in this manner forms a rather thin nerve, occasionally double, which pierces the fascia on the medial side of the upper arm below the insertion of the latissimus dorsi and is distributed to the skin of the medial side of the upper arm.

3. The *medial antibrachial (internal) cutaneous nerve* (Figs. 554, 595, 596, and 703), although stronger than the preceding, is weaker than the musculocutaneous. It arises from the medial fasciculus and contains fibers of the eighth cervical and first thoracic. At first it passes downward on the medial side of the brachial artery in front of the ulnar nerve, and then accompanies the basilic vein, with which it pierces the brachial fascia below the middle of the upper arm, and immediately divides into two branches. (*a*) The *volar ramus* passes in front of the lacertus fibrosus to the ulnar half of the volar surface of the forearm, and (*b*) the *ulnar ramus* accompanies the basilic vein toward the wrist-joint and ramifies on the ulnar surface of the forearm.

* The brachialis is innervated not only by the musculocutaneous, but also by branches from the radial nerve (see below).

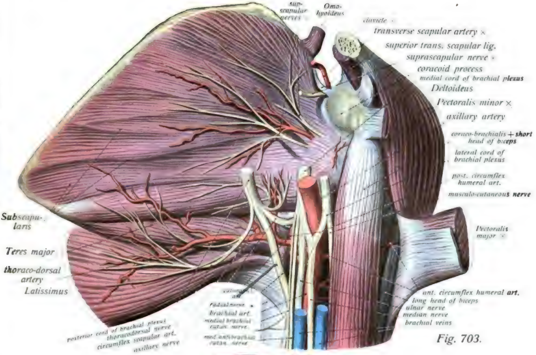


Fig. 703.

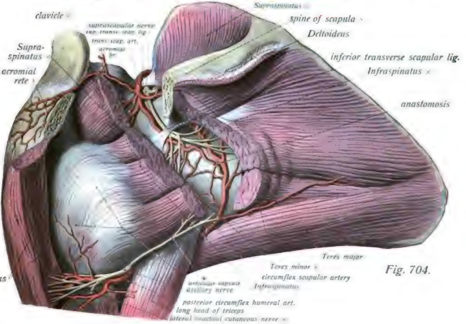


Fig. 704.

The Median Nerve.—The median nerve (Figs. 554, 555, 562, 563, 703, and 705 to 709), in location as well as in size the middle of the three brachial nerves, arises in the inferior part of the axillary fossa from two roots, which unite at an acute angle in front of the axillary artery, one having its origin from the medial, the other from the lateral fasciculus of the brachial plexus. The former derives its fibers mainly from the sixth and seventh cervical nerves, the latter from the eighth cervical and first thoracic. From the forked origin an almost circular stem arises, which in its upper part lies close to the brachial artery in the medial bicipital sulcus, but in the lower third of the upper arm gradually comes to lie first in front of the artery and then on its medial side. Then, directly covered by the lacertus fibrosus, it courses with the brachial artery into the cubital fossa.

Not until it reaches the bottom of this depression does the nerve branch, and it passes out of the fossa between the humeral and ulnar heads of the pronator teres and comes to lie deeply in the middle of the volar surface of the forearm, between the flexor digitorum sublimis and the flexor digitorum profundus. It continues onward to the wrist, and with the tendons of these muscles passes through the carpal canal and its terminal branches are distributed in the palm of the hand.

The median, like all the three large brachial nerves, is a mixed nerve, and its distribution is to the musculature of the flexor surface of the forearm and to the palm of the hand. In the upper arm it usually gives off no branches, with the exception of an occasional communicating branch to the musculocutaneous.* The branches of the median nerve are:

I. IN THE FOREARM: 1. *Muscular rami* (Figs. 706 and 707) for the pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum sublimis, and the radial half of the flexor digitorum profundus.

2. The *volar (antibrachial) interosseous nerve* (Fig. 707) is a long muscular branch intended for the pronator quadratus. With the corresponding artery it passes over the anterior surface of the antibrachial interosseous membrane to the muscle, and contains also a few sensory branches for the radiocarpal articulation.

3. The *palmar branch* (Figs. 562, 596, 706, and 712) arises above the wrist and passes with the tendon of the palmaris longus to the skin of the volar surface of the hand.

II. IN THE HAND. In the depth of the palm, that is to say, in the region of the carpometacarpal joints, the median nerve divides into three strong *common volar digital nerves* (Figs. 562 and 712), which pass below the superficial volar arch toward the fingers, each dividing in the region of the metacarpophalangeal joints into two (or three) *proper volar digital nerves* (Figs. 562 and 563), which are the sensory branches for the skin of the fingers and are seven in number. Beside supplying the three radial digits and the radial side of the fourth, the median nerve also supplies a few muscles in the palm of the hand by means of fine branches of the common digital nerves. From the first of these are supplied the abductor pollicis brevis, the opponens pollicis, the superficial head of the flexor pollicis brevis, and the radial lumbricalis. The second and third each give a branch to the second and third lumbricalis, and the third, by an oblique anastomosis, also unites with the volar branch of the ulnar.

* This anastomosis, when present, is to be regarded as a delayed rearrangement of the fibers of the plexus destined for the two nerves. By it the median transfers to the musculocutaneous fibers which properly belong to it.

FIG. 705.—The vessels and nerves of the flexor surface of the forearm. (Superficial layer.)

The lacertus fibrosus is divided and the brachioradialis drawn backward.

FIG. 706.—The vessels and nerves of the flexor surface of the forearm. (Deep layer.)

The pronator teres, palmaris longus, and flexor carpi radialis have been partly removed and the tendon of the flexor carpi ulnaris divided. - = Site of entrance of deep branch of radial nerve into the supinator. * = Ulnar head of pronator teres. ** = Radial head of flexor digitorum sublimis.

FIG. 707.—The deep layer of the nerves and vessels of the flexor surface of the forearm.

All the flexors and pronators of the superficial layer have been divided and the median nerve and flexor digitorum profundus drawn to one side.

FIG. 708.—The vessels and nerves of the ulnar side of the elbow.

The flexors and pronators of the forearm have been either divided or partly removed.

FIG. 709.—The vessels and nerves of the radial side of the elbow.

The radial group of the muscles of the forearm has been reflected and the supinator divided along the deep branch of the radial nerve. * = Radial head of flexor digitorum sublimis. ** = Anastomosis between ulnar recurrent and inferior ulnar collateral arteries.

The first common volar digital nerve supplies, in addition to the muscles mentioned, both borders of the thumb and the radial border of the index finger, furnishing, therefore, the *radial* and *ulnar proper volar digital nerve of the thumb* and the *radial proper volar digital nerve of the index;* the second common volar digital furnishes the *ulnar proper volar digital nerve of the index* and the *radial proper volar digital nerve of the third digit;* and the third common volar digital gives off the *ulnar proper volar digital nerve of the third digit* and the *radial proper volar digital nerve of the fourth digit.* Seven proper volar digital nerves, therefore, arise from the median nerve (see below).

The Ulnar Nerve.—The *ulnar nerve* (Figs. 554, 555, 703, and 705 to 709) is the smallest of the three large nerves of the arm. It arises from the medial fasciculus of the brachial plexus and contains fibers from the eighth cervical and first thoracic nerves, and also some from the seventh cervical. It is similar to the median nerve in that it does not branch until it reaches the forearm, in which it gives motor fibers to the muscles of the volar surface and sends sensory and motor fibers to the hand. In contrast to the median its distribution is not confined to the palm of the hand, but extends to the dorsum.

Below its origin from the brachial plexus it courses on the medial side of the brachial artery, then diverges from it, and in company with the superior collateral ulnar artery passes downward along the medial intermuscular septum, frequently enclosed by it, and passes behind the medial epicondyle, where it comes to lie between the two heads of the flexor carpi ulnaris. It then pierces the flexor carpi ulnaris and turns forward to the ulnar and volar surface of the forearm, between flexor carpi ulnaris and flexor digitorum profundus, and comes to lie close to the ulnar artery, along the ulnar side of which it passes to the wrist. A few centimeters above this joint, at the radial side of the tendon of the flexor carpi ulnaris, it divides into its terminal branches, a *volar* ramus which is the continuation of the stem, and a much smaller *dorsal* ramus. The branches of the ulnar nerve are:

I. IN THE FOREARM, in addition to a few sensory branches for the elbow joints:

1. *Muscular rami* (Fig. 708) to the flexor carpi ulnaris and to the ulnar half of the flexor digitorum profundus.

2. The *palmar cutaneous* (Figs. 596, 706, and 712), which is much smaller than the cor-

Fig. 705.

Fig. 706.

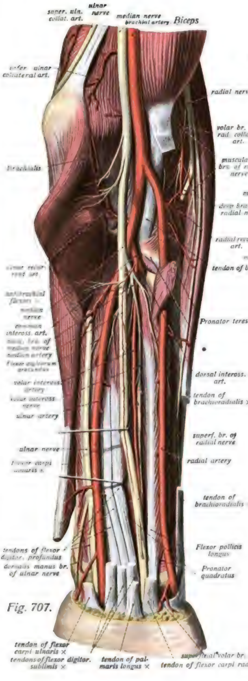


Fig. 707.

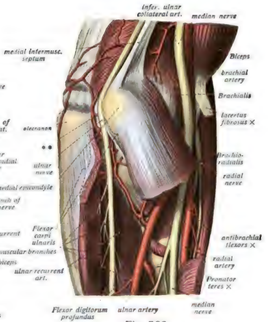


Fig. 708.

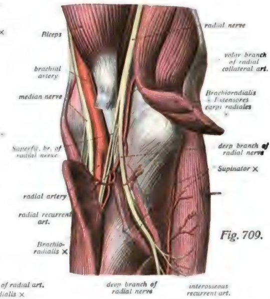


Fig. 709.

responding ramus of the median nerve, passes between the tendons of the flexor carpi ulnaris and flexor digitorum profundus, and perforates the antibrachial fascia above the wrist-joint. It supplies the skin of the ulnar portion of the palm, as well as the neighboring part of the lower end of the forearm.

II. IN THE HAND: 1. The *dorsal ramus* (Figs. 558, 559, 705, 707, and 713) passes above the styloid process of the ulna, between the ulna and the flexor carpi ulnaris to the dorsum of the hand. It is a purely sensory nerve and, besides giving off branches to the dorsal surface of the wrist joint and to the skin of the hand, it sends five *dorsal digital nerves* to the sides of the two ulnar digits and the ulnar side of the third (see below). It anastomoses in the metacarpal region (often doubly) with the superficial branch of the radial nerve.

2. The *volar ramus* (Fig. 562) is the real continuation of the trunk. It accompanies the ulnar artery and passes between it and the pisiform bone to the palm. Here it is covered by the palmaris brevis, which it supplies, and it then divides into its two terminals.

(*a*) The *superficial volar branch* (Fig. 562) is purely sensory and divides into two branches, the *ulnar proper volar digital nerve of the fifth digit* and the *fourth common volar digital nerve*. The latter anastomoses with the third common volar digital branch of the median nerve and divides into the *radial proper volar digital of the fifth digit* and the *ulnar proper volar digital of the fourth digit*.

(*b*) The *deep volar branch* (Fig. 708) is almost purely motor. It passes with the deep volar branch of the ulnar artery between the hypothenar muscles into the depth of the palm, innervates these muscles, and in addition gives muscular rami to the fourth lumbricalis, the adductor pollicis, all the interossei, and the deep head of the flexor pollicis. It accompanies the deep volar arch in the depth of the palm and gives off fine branches to the volar surface of the wrist and metacarpophalangeal articulations.

The Radial Nerve.—The radial nerve (*musculospiral*) (Figs. 554 to 557, 705, and 709) is the strongest of the three large nerves in the arm. It arises from the posterior cord of the brachial plexus and contains mainly fibers from the sixth, seventh, and eighth cervical nerves. At its origin it lies behind the brachial, or rather the axillary artery, but soon separates from it, passing with the deep brachial artery between the long and medial head of the triceps. Then, at first accompanied by the deep brachial, and later by the radial collateral artery, it curves forward around the posterior surface of the humerus in the groove for the radial nerve between the heads of the triceps, and comes to lie in the groove between the brachioradialis and brachialis, that is to say, at the bottom of the cubital fossa, where it divides into its two terminal branches, the weaker, purely sensory, *superficial ramus* going to the dorsum of the hand, and the stronger, almost purely motor, *deep ramus*, which passes to the posterior surface of the antibrachium, and does not extend beyond the wrist. The main distribution of the radial nerve, which like the other two large arm nerves is a mixed nerve, is to the upper arm and forearm. The weaker terminal branch alone reaches the hand, and is distributed only to the dorsum. Besides giving muscular branches to all the extensors of the upper extremity the radial nerve also sends cutaneous branches to the posterior surface of the arm.

The branches of the radial nerve are:

I. IN THE UPPER ARM: 1. The *posterior brachial cutaneous nerve* (Figs. 556 and 710)

FIG. 710.—The cutaneous nerves and veins of the extensor surface of the upper arm.

FIG. 711.—The cutaneous nerves and veins of the extensor surface of the forearm.

* = Accessory cutaneous branch from axillary nerve. ** = Anastomosis between posterior brachial and dorsal antibrachial cutaneous nerves. *** = Anastomosis between dorsal antibrachial cutaneous and radial nerves. † = Cutaneous branches of posterior circumflex vessels of humerus. †* = Cutaneous branches of thoraco-acromial vessels.

FIG. 712.—The superficial nerves and vessels of the palm.

* = Cutaneous branch of the ulnar nerve. ** = Volar cutaneous branches of the median and ulnar nerves. † = Volar digital artery of thumb.

FIG. 713.—The superficial nerves and veins of the back of the hand.

†† = Anastomosis between ulnar and radial nerves.

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pierces the fibers of the lateral head of the triceps and comes to the surface at about the level of the deltoid insertion, supplying the skin on the posterior surface of the upper arm. It is not always present and may be replaced by the dorsal antibrachial cutaneous nerve.

2. *Muscular rami* (Figs. 557 and 705 to 707) to the triceps,* the anconaeus,† the brachioradialis, and the radial side of the brachialis.

3. The *dorsal antibrachial cutaneous nerve* (Figs. 556, 557, 710, and 711) is much larger than the brachial cutaneous. It comes to the surface at the lateral intermuscular septum between the lateral and medial heads of the triceps, it accompanies the dorsal terminal branch of the radial collateral artery, and pierces the deep fascia above the elbow joint. It is distributed to the skin of the dorsal surface of the forearm and extends down almost to the wrist.

II. IN THE CUBITAL FOSSA. In the depth of the cubital fossa muscular branches, going to the radial group of muscles of the forearm, leave the trunk of the radial nerve just before it divides into its two terminal branches.

III. The *superficial ramus of the radial nerve* (*radial nerve*) (Figs. 596, 705, 711, and 713), although the smaller of the two terminals, continues in the direction of the main trunk. Covered by the brachioradialis it passes along the radial side of the radial artery, but not so close to it as the ulnar nerve is to the ulnar artery, and above the styloid process of the radius it passes between the bone and the tendon of the brachioradialis and goes to the posterior surface of the lower end of the forearm. Here the nerve pierces the antibrachial fascia and divides usually into two branches, of which the radial anastomoses with the lateral antibrachial cutaneous and the ulnar, by means of the *anastomosing ulnar ramus*, which is often double, with the ulnar nerve. The five radial *dorsal digital nerves* arise from these two branches (see below).‡

IV. The *deep ramus of the radial nerve* (*posterior interosseous nerve*) (Figs. 558, 559, 705, and 709), the larger, motor terminal ramus, usually, after piercing the supinator, curves to the dorsal surface of the forearm and supplies, in addition to the supinator, all the antibrachial extensors. It accompanies the dorsal interosseous artery, lying between the superficial and deep layer of the antibrachial extensors, and its terminal branch is a fine sensory *dorsal interosseous nerve*, which passes to the dorsal surface of the carpometacarpal joints and accompanies the dorsal terminal portion of the volar interosseous artery (see page 48).

* A branch of the radial passing to the lower part of the medial head of the triceps often accompanies the ulnar nerve (ulnar collateral) in a common sheath.

† The muscular branch for the anconaeus passes in the substance of the medial head of the triceps and also sends sensory branches to the elbow.

‡ A few branches of the radial nerve pass over the radial border of the thumb to the skin of the thenar eminence.

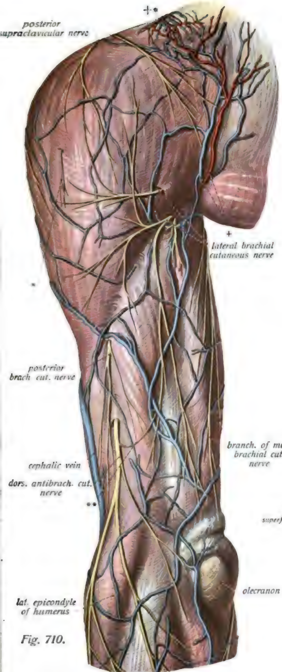

Fig. 710.

Fig. 711.

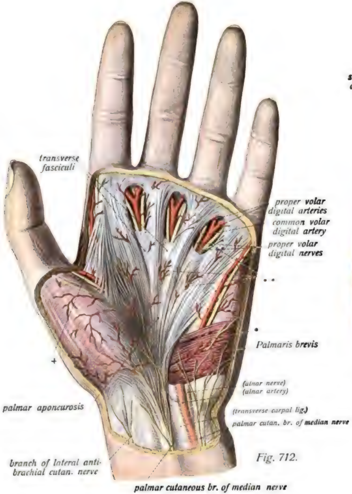

Fig. 712.

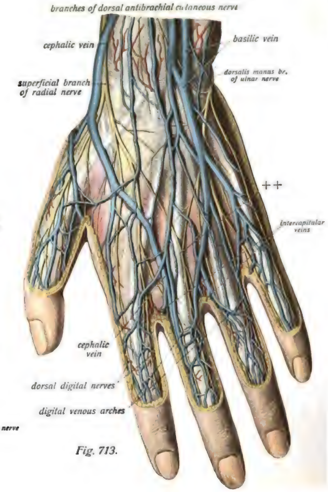

Fig. 713.

THE NERVES OF THE FINGERS.

Just as every finger receives four arteries, so it possesses four sensory nerves (Figs. 562, 563, 712, and 713), and exactly as in the arteries, the volar nerves are decidedly stronger than the dorsal ones, and, furthermore, the volar nerves supply also the dorsal surfaces of the terminal phalanges. Of the *proper volar digital nerves,* the seven radial ones arise from the median nerve and the three ulnar ones from the *ulnar.* The middle eight arise from the division of four *common volar digitals,* of which the three radial ones belong to the median nerve, the ulnar one to the ulnar nerve. The proper volar digital nerves lie medially to the corresponding arteries.

The *dorsal digital nerves* are much weaker than the volars, and the five radial ones arise from the superficial ramus of the radial nerve, the five ulnar ones from the ramus of the ulnar nerve, which passes to the dorsum of the hand.

Innervation of the Muscles of the Upper Extremity.

I. Shoulder muscles:
   Deltoid + *Teres minor* = *axillary nerve.*
   Teres major (+ *Latissimus*) = *thoracodorsal nerve* } *subscapular nerves.*
   Subscapularis = *subscapular rami* }
   Supraspinatus + *Infraspinatus* = *suprascapular nerve*

II. Upper arm muscles:
   Biceps, Coracobrachialis, and the greater part of the Brachialis = *musculocutaneous nerve.*
   Triceps + *Anconaeus, Brachialis* (partly) = *radial nerve.*

III. Forearm muscles:
   Pronator teres, Flexor carpi radialis, Palmaris longus, Flexor digitorum sublimis, Flexor digitorum profundus (half) and *Pronator quadratus* = *median nerve.*
   Flexor carpi ulnaris, Flexor digitorum profundus (half) = *ulnar nerve.*
   Brachioradialis, Extensores carpi radiales = *radial nerve.*
   Supinator, Extensor digitorum communis, Extensor carpi ulnaris, Extensor digiti V propr. } *deep ramus of the*
   Extensor indicis propr., Extensor pollicis, Abductor pollicis longus } *radial nerve.*

IV. Hand muscles:
   Abductor pollicis brevis, Opponens pollicis, Flexor pollicis brevis (partly), *Lumbricales* (two to three) = *median nerve.*
   Adductor digiti V, Flexor brevis digiti, Opponens digiti V, Abductor pollicis brevis, Flexor pollicis brevis (partly), *Lumbricales* (one to two), *Interossei dorsales* and *volares* = *ulnar nerve (deep volar ramus).*

The Sensory Skin Areas of the Upper Extremity.

Shoulder: Upper part (*acromial region* and upper part of the *deltoid region*) = *posterior supraclavicular nerves.* Lower part (*deltoid region*) = *lateral brachial cutaneous nerve.*

lary fossa: Skin of the *axillary fossa* = *intercostobrachial* and *medial brachial cutaneous nerves.*

pper arm: *Lateral brachial region* = *lateral brachial cutaneous nerve* (and *posterior brachial cutaneous*). *Posterior brachial region* = *posterior brachial cutaneous nerve. Anterior brachial region* = *medial brachial cutaneous nerve. Medial brachial region* = *medial brachial cutaneous nerve. Posterior cubital region* = *medial antibrachial cutaneous* and *dorsal antibrachial cutaneous nerves. Lateral cubital region* = *dorsal antibrachial cutaneous nerve. Medial cubital region* = *medial antibrachial cutaneous nerve. Anterior cubital region* = *medial* and *lateral antibrachial* and *medial brachial cutaneous nerves.*

Forearm: *Dorsal antibrachial region* = *dorsal antibrachial cutaneous nerve. Ulnar antibrachial region* = *medial antibrachial cutaneous nerve — ulnar branch. Radial antibrachial region* = *lateral antibrachial cutaneous nerve. Volar antibrachial region* = *medial antibrachial cutaneous nerve — volar branch.*

Hand: *Dorsal region* = *dorsal ramus of ulnar nerve* and *superficial ramus of radial nerve* (partly also the *lateral antibrachial cutaneous nerve*). *Dorsal digital region* = *ulnar ne[illegible] dorsal ramus* and *radial nerve*

posterior cu

FIG. 714.—The superficial and middle layer of the nerves and vessels of the nuchal region.
Upon the left side the trapezius, sternocleidomastoideus, splenius, and levator scapulæ have been divided.
* = Occipital root of external jugular vein.

(*superficial ramus*) (see pages 223 and 225). *Volar region* = *palmar ramus of median nerve* and *palmar ramus of ulnar nerve*. *Volar digital region* = *median nerve* (the borders of three and a half fingers) and *superficial volar ramus of ulnar nerve* (the borders of one and a half fingers) (see pages 222 and 223).

THE THORACIC NERVES.

There are twelve pairs of thoracic nerves which pass through the intervertebral foramina of the vertebral column, the last one through the foramen between the twelfth thoracic and first lumbar vertebræ. Like all spinal nerves, they divide into a stronger anterior and a weaker posterior branch. The first thoracic nerve is the largest, the middle ones are the weakest, the lower two or three again being decidedly larger than the middle ones.

Posterior Rami of the Thoracic Nerves.—The posterior rami of the thoracic nerves (Figs. 696 and 714) pass behind the anterior (but in front of the posterior) costotransverse ligaments into the deeper portions of the dorsal groove and are mixed nerves, carrying motor fibers for the (deep) muscles of the back as well as sensory fibers for the skin. Each ramus divides into a medial and a lateral branch, the lateral ones being the stronger in the upper nerves and the medial ones in the lower; this is especially true of the terminal sensory branches to the skin of the back.

1. The *medial cutaneous ramus* is distributed to the deep layers of the muscles of the back (short and long muscles), pierces the flat muscles of the back (trapezius) without innervating them, and terminates in the skin of the middle dorsal region, and above, also, in the neighboring lateral dorsal region.

2. The *lateral cutaneous ramus* supplies the lateral portions of the long muscles of the back and terminates in the cases of the five lower thoracic nerves in long twigs which penetrate the latissimus dorsi to reach the integument.

The Anterior Rami or Intercostal Nerves.—The anterior rami of the thoracic nerves are the *intercostal nerves* (Figs. 538 and 587), and are the only anterior rami of the spinal nerves which do not form a plexus, but apart from a few occasional delicate anastomoses remain entirely independent. Each intercostal receives a communicating ramus from a neighboring sympathetic thoracic ganglion, and then, in correspondence with the course of the ribs, passes laterally and forward in the intercostal space. The twelfth intercostal runs parallel to the lower border of the twelfth rib (subcostal nerve).

At first each intercostal nerve lies near the head of the rib, below the intercostal artery, and directly covered by the costal pleura and the endothoracic fascia; it then passes between the intercostal muscles, lying in front of the internal but behind the external, at about the middle of the height of the intercostal space. The lower nerves pass between the false ribs and anteriorly are continued onward between the flat abdominal muscles.

The first intercostal nerve is very weak, since the main part of the anterior ramus of the first thoracic nerve takes part in the formation of the brachial plexus. The large twelfth inter-

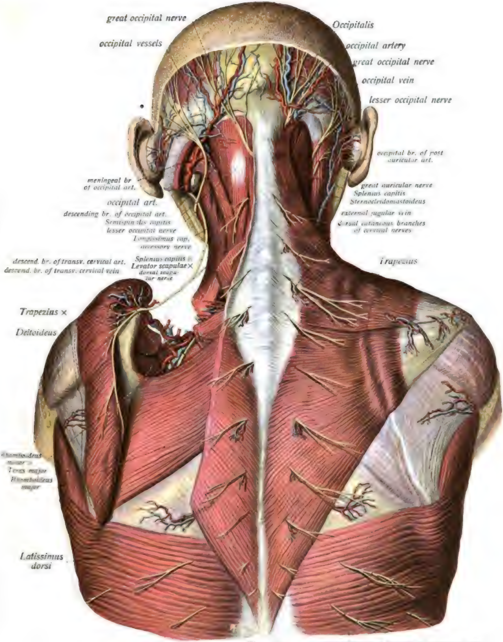
great occipital nerve
occipital vessels
Occipitalis
occipital artery
great occipital nerve
occipital vein
lesser occipital nerve
occipital br. of post auricular art.
meningeal br of occipital art.
occipital art.
descending br. of occipital art.
Semispinalis capitis
lesser occipital nerve
Longissimus cap.
accessory nerve
great auricular nerve
Splenius capitis
Sternocleidomastoideus
external jugular vein
dorsal cutaneous branches of cervical nerves
descend. br. of transv. cervical art.
descend. br. of transv. cervical vein
Splenius capitis
Levator scapulae ×
dorsal scapular nerve
Trapezius
Trapezius ×
Deltoideus
Rhomboideus minor ×
Teres major
Rhomboideus major
Latissimus dorsi
posterior cutaneous branches of intercostal nerves

Fig. 714.

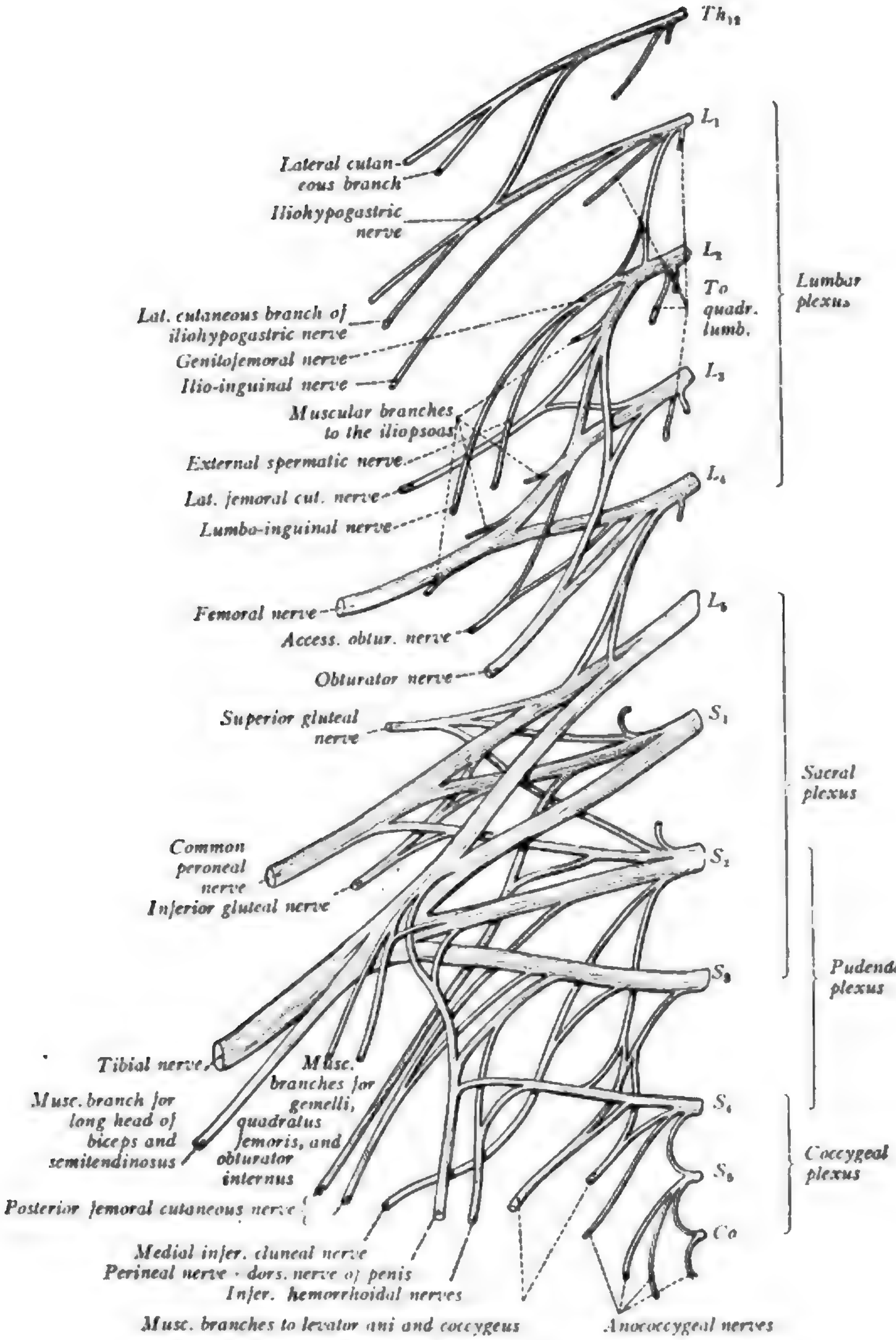

FIG. 715.—The plan of the lumbosacral plexus (after P. Eisler).

costal at first follows the course of the twelfth rib, then passes obliquely in front of the quadratus lumborum, and sinks into the anterior lamina of the lumbodorsal fascia, runs between the flat abdominal muscles obliquely downward and terminates in muscular rami to the rectus abdominis and pyramidalis.*

Each intercostal, being a mixed nerve, contains motor fibers which form *muscular rami* innervating the intercostal muscles (including the subcostales, transversus thoracis, and levatores costarum) and also the two serrati posteriores. In addition they give branches to the skin of the thorax, the inferior ones also to the skin of the abdomen, along two distinct lines, one anterior and one lateral.

The *lateral cutaneous rami* (Figs. 552 and 594) are known according to the level at which they appear as *pectoral* or *abdominal cutaneous rami*, and pass between the digitations of the serratus anterior, or in the abdomen between the fibers of the obliquus externus, and divide each into an *anterior* and a *posterior ramus*. The anterior rami of the pectoral branches pass to the lateral portion of the skin of the thorax, the posterior to the skin of the back, the anterior branches of the fourth to the sixth nerves giving off *lateral mammary rami* to the mammary gland. The lateral abdominal cutaneous branches are larger than the pectoral and ramify in the skin of the lateral abdominal region.

The *anterior cutaneous rami* (Fig. 593) may be also divided into *pectoral* and *abdominal rami*. They arise from the anterior end of each intercostal nerve, and the pectoral rami pierce the pectoralis major with the perforating branches of the internal mammary artery near the sternal border, and ramify in the sternal and mammary regions, branches from the fourth to the sixth passing to the mammary gland (*medial mammary nerves*). The abdominal branches from the lower intercostal nerves penetrate into the abdominal musculature and supply the upper parts of the rectus abdominis and parts of the flat abdominal muscles, also sending cutaneous branches to the anterior part of the skin of the abdomen.

The first intercostal nerve, most of which goes to the brachial plexus (medial fasciculus), has no cutaneous branch. The lateral cutaneous branch of the second intercostal, and often also that of the third, unites in the axillary fossa with the medial brachial cutaneous nerve; these anastomoses, which are with a branch of the medial fasciculus of the brachial plexus, being called *intercostobrachial nerves*.

THE LUMBAR, SACRAL, AND COCCYGEAL NERVES.

The five *lumbar* and five *sacral nerves* and the *coccygeal nerve* are similar in many respects. Their anterior branches form a common, large plexus, the *lumbosacral plexus*. The short trunks of the lumbar nerves pass through the intervertebral foramina of the lumbar vertebræ, the last one through the intervertebral foramen between the last lumbar vertebra and sacrum, and increase considerably in thickness from above downward. The trunks of the sacral nerves divide while still within the sacral canal into anterior and posterior rami, which pass out separately through the anterior and posterior sacral foramina,† and usually decrease in size from above downward, so that usually the first, more rarely the second sacral nerve, is the largest, and the

* The upper part of these muscles is supplied by the anterior abdominal cutaneous rami.

† The weak fifth sacral nerve emerges at the inferior border of the sacrum.

fifth by far the smallest. The very small coccygeal nerve divides at the level of the coccygeal cornu into its two branches.

The Posterior Rami of the Lumbar, Sacral, and Coccygeal Nerves.—The posterior rami of the lumbar nerves are much smaller than the anterior ones. They resemble greatly the posterior thoracic rami and convey motor fibers for the lumbar portions of the deeper muscle layers of the back and sensory fibers for the skin of the lumbar and upper half of the gluteal region. Each posterior branch divides into a *medial ramus*, whose sensory branches pass to the skin of the lumbar region, and a lateral ramus, whose sensory branches, especially those of the inferior and medial lumbar nerves, pass as rather strong, partly anastomosing branches across the iliac crest to the skin of the upper half of the gluteal region, and are known as the *superior cluneal nerves* (Fig. 719).

The posterior rami of the sacral nerves and of the coccygeal nerve are even smaller than those of the lumbar nerves, and are, indeed, the smallest posterior rami of all the spinal nerves. Those of the upper four sacral nerves pass through the posterior sacral foramina, and in contrast to the posterior rami of the thoracic and lumbar nerves, these posterior sacral rami are purely sensory. They divide into small *medial rami* to the skin over the posterior surface of the sacrum, and somewhat larger *lateral rami*, which, together with the posterior rami of the lower lumbar nerves, form the *middle cluneal nerves.* These pierce the origins of the gluteus maximus and supply a part of the skin of the gluteal region. The posterior ramus of the coccygeal nerve takes part in the formation of the *anococcygeal nerves* (see page 238).

THE LUMBOSACRAL PLEXUS.

From the union of the anterior rami of the lumbar and the sacral nerves a strong plexus is formed, which is the largest of the whole body and is known as the *lumbosacral plexus* (Figs. 715 and 716). It is again divisible into three subdivisions, the *lumbar*, the *sacral*, and the *pudendal plexuses*, and finally the coccygeal nerve with a part of the fifth sacral also forms a small *coccygeal plexus.* The anterior rami of the last lumbar and the first two sacral nerves represent the largest roots of the plexus. They enter into the formation of the largest, or sacral plexus, the first two, that is to say the fifth lumbar and first sacral, usually strengthened by a branch from the fourth lumbar, uniting to form a very large nerve cord, the *lumbosacral trunk.* Toward the first lumbar nerve the size of the rami decreases slowly, but toward the fifth sacral quickly, so that the latter is very weak and the anterior ramus of the fourth sacral nerve also is of very small size. The anterior rami of all these nerves communicate with the corresponding sympathetic ganglia by rami communicantes.

THE LUMBAR PLEXUS.

The *lumbar plexus* (Figs. 715 and 716) is formed by the union of the anterior rami of the first to the fourth lumbar nerves, the anterior ramus of the last, however, usually not entering completely into the formation of this plexus, which lies partly behind the psoas major, but for the most part between its bundles. The branches of the plexus are distributed partly to the abdominal wall and partly to the lower extremity, the largest nerve of the plexus, the femoral, extending by its terminal branches to the foot. The main nerves of the plexus lie behind the parietal peri-

FIG. 716.—The nerves of the lumbar plexus and the blood-vessels of the posterior abdominal wall.

All the abdominal viscera have been removed and the unpaired branches of the abdominal aorta and the renal arteries cut away. The left common iliac artery and vein, with the proximal portions of their branches, have been removed, together with the greater portion of the psoas major, to show the formation of the lumbar plexus. * = Psoas minor.

toneum and the kidneys, in front of the psoas, quadratus lumborum, and iliacus. Only the obturator nerve runs through the true pelvis. In addition to *muscular rami* to the psoas major and minor and to the quadratus lumborum the following nerves arise, as a rule,* from the lumbar plexus:

1. The **iliohypogastric nerve** (Fig. 716), of moderate size, and containing both sensory and motor fibers, arises from the first lumbar, but usually receives a contribution from the last intercostal nerve. It generally pierces the upper part of the psoas major and then courses behind the kidney and the parietal peritoneum, running obliquely across and downward upon the anterior surface of the quadratus lumborum, and, above the iliac crest, it pierces the transversus and terminates between the flat abdominal muscles which it supplies by its *muscular rami*. In addition to these the nerve gives off two main branches: the *lateral cutaneous ramus* (Fig. 719) which pierces the posterior part of the external oblique muscle above the iliac crest and passes to the skin of the hip region, and the *anterior cutaneous ramus*, which pierces the aponeurosis of the external oblique muscle above the external abdominal ring and passes to the neighboring portions of the abdominal integument and to the mons pubis.

2. The **ilio-inguinal nerve** (Fig. 716) is also a mixed nerve, but is weaker than the preceding and inconstant, being often replaced by it. It also arises from the first lumbar nerve, pierces the psoas major, and passes almost parallel to the iliohypogastric, across the anterior medial surface of the iliacus to the region of the anterior superior spine of the ilium. Here it traverses the flat abdominal muscles, giving branches to them, courses through the inguinal canal, and passes out through the external abdominal ring. Its sensory branches are distributed partly to the skin of the mons pubis (Fig. 600), but especially as the *anterior scrotal* (in the female, *labial*) *nerves* (Fig. 591) to the skin of the root of the penis and the anterior surface of the scrotum (in the female to the labia majora).

3. The **lateral femoral cutaneous nerve** (Figs. 600, 716, and 719) is purely sensory and arises from the second and third lumbar nerves. It either pierces the psoas major or appears at its lateral border, either independently or with the root of the femoral nerve. It passes obliquely in front of the iliacus to below the anterior superior spine of the ilium, where it pierces the abdominal wall below the deep circumflex iliac artery and, piercing the fascia lata, becomes cutaneous at the medial side of the origin of the sartorius. It is distributed by several branches, some of which are long and strong, to the skin of the lateral border and the lateral part of the anterior surface of the thigh.

4. The **genitofemoral (genitocrural) nerve** (Fig. 716) is also a mixed nerve. It arises mainly from the second lumbar nerve, pierces the psoas major, and courses downward

* The number of nerves of the plexus is frequently diminished by the blending of the iliohypogastric and ilio-inguinal nerves, but it may, on the other hand, be increased by the two branches of the genitofemoral nerves being separated.

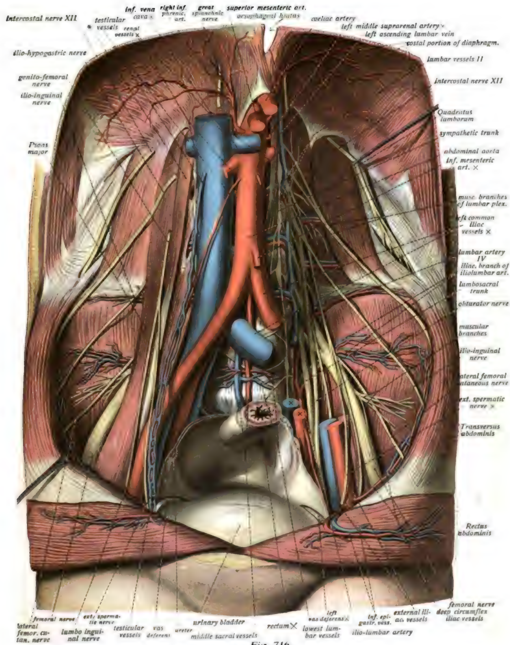
Intercostal nerve XII
testicular vessels *
renal vessels ×
inf. vena cava ×
right inf. phrenic. art.
great splanchnic nerve
superior mesenteric art.
oesophageal hiatus
coeliac artery
left middle suprarenal artery ×
left ascending lumbar vein
costal portion of diaphragm.
lumbar vessels II
Intercostal nerve XII
ilio-hypogastric nerve
genito-femoral nerve
ilio-inguinal nerve
Psoas major
Quadratus lumborum
sympathetic trunk
abdominal aorta
inf. mesenteric art. ×
musc. branches of lumbar plex.
left common iliac vessels ×
lumbar artery IV
iliac. branch of iliolumbar art.
lumbosacral trunk
obturator nerve
muscular branches
ilio-inguinal nerve
lateral femoral cutaneous nerve
ext. spermatic nerve ×
Transversus abdominis
Rectus abdominis
lateral femor. cutan. nerve
femoral nerve
lumbo inguinal nerve
ext. spermatic nerve
testicular vessels
vas deferens
ureter
urinary bladder
middle sacral vessels
rectum ×
left vas deferens ×
lowest lumbar vessels
inf. epigastr. vess.
ilio-lumbar artery
external iliac vessels
femoral nerve
deep circumflex iliac vessels

Fig. 716.

along its anterior surface beside the tendon of the psoas minor. At a variable level it divides at an acute angle into its two terminal branches.

(*a*) The *external spermatic nerve* (*genital branch*) (Figs. 600 and 716) is the lateral terminal branch of the genitofemoral. It passes obliquely across the external iliac vessels to the inguinal canal, which it traverses, and as a constituent of the spermatic cord emerges at the external abdominal ring. It is distributed to the sheaths of the spermatic cord, partly also to the scrotum, and supplies the cremaster muscle.

(*b*) The *lumbo-inguinal nerve* (*crural branch*) (Fig. 600) is purely sensory. It courses upon the psoas major and lateral to the external iliac artery to the inguinal ligament, below which it enters the thigh, pierces the fascia lata, and is distributed to the skin of the subinguinal region.

5. The **femoral (anterior crural) nerve** (Fig. 716) is by far the largest nerve of the plexus and is a mixed nerve, as are also most of its branches. It arises from the second to the fourth lumbar nerves and courses down in the groove between psoas and iliacus, but covered by the lateral border of the psoas major, gives off a few *muscular rami* to the iliacus in the false pelvis, and then passes with the iliopsoas through the muscular lacuna to the thigh. Behind the inguinal ligament the nerve lies close to and lateral to the femoral artery, but separated from it by the iliopectineal fascia,* and just below the inguinal ligament, in the lateral part of the iliopectineal fossa, it splits up into its terminal branches. These are:

(*a*) The *anterior femoral cutaneous rami* (the middle and internal cutaneous nerves) (Fig. 600) are from two to four sensory branches, which pierce the fascia lata at a variable height, but usually above the middle of the thigh, and supply the skin of the anterior and medial surfaces of the thigh down to the knee. One of the branches often pierces the sartorius before passing through the fascia, and another accompanies the femoral portion of the great saphenous vein.

(*b*) *Muscular rami* (Figs. 573 to 575) to all four heads of the quadriceps and to the pectineus and sartorius. They may be divided into short branches which, even in the iliopectineal fossa, approach their muscles (pectineus, sartorius, rectus), and long branches to the vasti and partly also to the rectus. The longest courses parallel to the following nerve and to the femoral artery upon the vastus medialis almost down to the knee-joint, and contains, besides the motor fibers for this muscle, also sensory fibers for the knee-joint.

(*c*) The *saphenous nerve* (Figs. 574, 575, 601, and 720) is the real terminal branch of the femoral nerve and is by far its longest branch, since it extends to the foot. It accompanies the femoral artery to the adductor hiatus, lying at first lateral and then anterior to it, and then courses along the tendon of the adductor magnus to the medial surface of the knee-joint. In the region of the medial condyle of the tibia it pierces the fascia lata near the tendon of the sartorius and passes down the leg subcutaneously, close to the long saphenous vein, to the medial border of the foot. Just before it becomes subcutaneous it sends an *infrapatellar ramus* to the skin of the medial side of the knee and the neighboring portions of the leg, this branch sometimes piercing the lower end of the sartorius. In the leg it sends numerous branches, the *medial crural cutaneous nerves* to the skin of the medial and anterior surfaces of the leg and to the middle portion of the calf.

* Since this fascia separates the lacunæ vasorum and musculorum the artery is in the first and the nerve in the latter.

FIG. 717.—The nerves and vessels of the posterior gluteal region (deep layer).

The gluteus maximus, gluteus medius, quadratus femoris, and the sciatic nerve have been divided. * = Muscular branch to the gemelli. ** = To the quadratus femoris.

FIG. 718.—The nerves and vessels of the popliteal space (superficial layer).

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6. The **obturator nerve** (Figs. 568, 574, 575, and 716) is principally a motor nerve. It arises from the second, third, and fourth lumbar nerves and is the only nerve of the plexus that emerges at the medial border of the psoas, behind the common iliac vessels. It runs forward and downward to the obturator canal, just below the linea terminalis on the upper portion of the lateral wall of the true pelvis, along with the obturator artery, but lying above it. It traverses this canal, giving off muscular branches to the two obturator muscles, and immediately after making its exit from the canal it divides into its two terminal branches. The *anterior ramus* is stronger than the posterior, and supplies the gracilis, the adductor brevis, the adductor longus, and sometimes also (partly) the pectineus. Above the insertion of the adductor longus its sensory terminal branch appears, pierces the fascia, and gives off a *cutaneous ramus* (often double) to the skin of the medial side of the thigh, this being the only large sensory branch of the nerve. The weaker *posterior ramus* gives off fine branches to the capsule of the hip-joint and supplies, in addition to the external obturator, the adductor minimus and the main portion of the adductor magnus.

THE SACRAL PLEXUS.

The *sacral plexus* (Figs. 568, 715, 716, and 727), at its origin, is not sharply defined from the pudendal plexus. It arises mainly from the very strong anterior rami of the fifth lumbar and the first two sacral nerves, but through the lumbosacral trunk (page 229) it also receives part of the fourth lumbar nerve and in addition a large part of the third and (sometimes) a small part of the fourth sacral nerve, which otherwise contribute to the formation of the pudendal plexus. The sacral plexus is the strongest plexus of the whole body. It lies in the true pelvis in the form of broad, flat fasciculi, converging toward the greater sciatic foramen, lateral to and behind the hypogastric artery and in front of and medial to the piriformis muscle. Its constituents usually unite in the region of this foramen to a single, flattened, broad nerve trunk, the main mass of which enters into the formation of the largest trunk of the plexus, the sciatic nerve. The main mass of the plexus then traverses the foramen below the piriformis (infrapiriform foramen), the superior gluteal nerve alone passing through above the muscle, and it supplies all parts of the lower extremity which are not innervated by the lumbar plexus. Its branches are:

1. The **superior gluteal nerve** (Fig. 717) is purely motor. It arises from the fifth lumbar and the first two sacral nerves, gives off branches to the piriformis, and, with its corresponding artery, passes through the so-called suprapiriform foramen to the gluteus medius and to the gluteus minimus, between which it passes. Its ultimate branches terminate in the tensor fasciæ latæ.

2. The **inferior gluteal nerve** (Figs. 577 and 717) is also purely motor and also arises from the fifth lumbar and the upper two sacral nerves. It courses with the main part of the plexus through the infrapiriform foramen, accompanying the corresponding artery, and ramifies

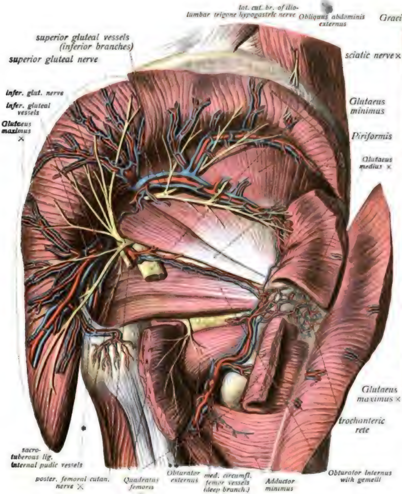

Fig. 717.

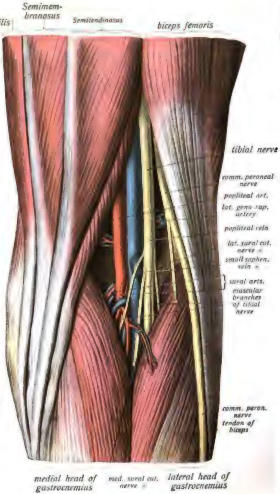

Fig. 718.

in the gluteus maximus, often also in the internal obturator and the gemelli, and sometimes in the quadratus femoris.*

3. The **posterior femoral cutaneous (small sciatic) nerve** (Figs. 576, 717, 719, and 720) is sensory. It arises from the first and second, and, to a small extent also from the third sacral nerve, passes through the infrapiriform foramen with the main part of the plexus, and accompanies the sciatic nerve to the medial (lower) border of the gluteus maximus. Here it gives off two or three rather strong stems which wind about the border of the muscle and pass to the skin of the lower half of the gluteal region, the *inferior* (*lateral*) *cluneal nerves*, also branches to the skin of the perineum, known as the *perineal rami*. The main stem passes from the inferior border of the gluteus maximus vertically downward, parallel to the sciatic nerve but separated from it by the flexor muscles, and becomes the cutaneous nerve for the posterior surface of the thigh and for the popliteal region. It is subfascial for the greater part of its course, not subcutaneous like other cutaneous nerves, and it sends its branches through the fascia; only the lower end of the nerve passing to the skin over the popliteal space is subcutaneous.

4. The **sciatic nerve**. By far the largest part of the sacral plexus enters into the formation of this largest (mixed) nerve of the body. It is a large, and at first a flat cord a good centimeter wide, and passes out from the true pelvis into the posterior hip region through the so-called infrapiriform foramen. Here it is covered by the gluteus maximus and lies behind the piriformis, the internal obturator, and the gemelli, and, a little further down, behind the quadratus femoris and the adductor minimus. In this part of its course it gives off separate muscular branches to the piriformis, the gemelli, and the quadratus femoris.

On the posterior surface of the thigh the sciatic nerve passes almost horizontally downward. Above, it lies behind the adductor magnus and in front of the origins of the flexors (the semitendinosus, the long head of the biceps, and the semimembranosus), and a little lower down it has the same relation to the adductor magnus and rests on the anterior surface of the flexors, but now lying in the groove between the semitendinosus and semimembranosus on one side and the biceps on the other. At a variable level, usually about the middle of the length of the thigh, or even a little higher,† it divides into its two terminals, the larger *tibial nerve* and the weaker *common peroneal nerve*.

(a) THE TIBIAL NERVE.

The *tibial nerve* (Figs. 577, 579 to 581, and 718) is the larger terminal branch of the sciatic and contains fibers from the fifth lumbar, but especially from the first to the third sacral nerves. It continues exactly in the direction of the trunk, and in the thigh gives off *muscular rami* to the long head of the biceps, the semitendinosus and the semimembranosus, and then passes diagonally from above downward through the popliteal fossa, lying lateral to and behind the popliteal vein and, therefore, nearer to the integument covering the popliteal fossa than the vein. In company with the popliteal vessels it then enters the popliteal canal, and after the division of the popliteal artery it accompanies the posterior tibial artery, lying on its lateral surface, between

* The branches to these muscles usually arise from the first part of the sciatic nerve.

† The division of the sciatic nerve really takes place far above the point of the apparent separation of its constituents. Thus is explained the fact that the nerve may emerge from the true pelvis already divided, in which case one part often pierces the piriformis.

FIG. 719.—The superficial nerves and veins of the buttock and of the posterior surface of the thigh.
* = Anastomotic vein from the great saphenous.

FIG. 720.—The superficial nerves and veins of the posterior surface of the leg (and of the dorsum of the foot).
** = Termination of the small saphenous in the popliteal vein. *** = Communication with deep veins.

the deep flexors of the leg (tibialis posterior and flexor digitorum longus) and the soleus, and descends to the foot. With the artery it passes between the tendon of Achilles and the medial malleolus, being covered by the laciniate ligament, and divides in this situation, usually earlier than the artery (page 71), into its two terminal branches, the medial and lateral plantar nerves.

The branches of the tibial in the leg are as follows:

1. *Muscular rami* (Figs. 579 and 581) from the upper part of the nerve to the triceps suræ, plantaris, popliteus. Other muscular branches for the tibialis posterior, flexor digitorum longus and flexor pollicis longus, and partly also for the soleus, are given off below the popliteal canal, and from one of these branches a fine nerve filament is given off, which passes along the posterior surface of the interosseous membrane, supplies it, as well as the two bones of the leg, and extends to the talocrural articulation; this is the *crural interosseous nerve*.

2. The *medial sural cutaneous nerve* (*communicans poplitei*) (Fig. 720) arises from the tibial while it is still in the popliteal space. It runs down the calf in the groove between the two heads of the gastrocnemius, together with the small saphenous vein; at about the middle of the length of the leg it pierces the crural fascia and unites with the anastomotic peroneal ramus (see below) to form the *sural* (*external or short saphenous*) *nerve*. This accompanies the small saphenous vein to the dorsum of the foot, passing between the lateral malleolus and the insertion of the calcaneal tendon, and gives off *lateral calcaneal rami* to the skin of the heel. Upon the dorsum of the foot it is known as the *lateral cutaneous nerve of the dorsum of the foot*, and ramifies in the lateral border of the foot, especially the dorsal part, anastomosing with the intermediate cutaneous nerve of the dorsum of the foot (see below), and terminates as the *lateral* (*fibular*) *dorsal digital nerve of the fifth digit* (Fig. 721).

3. The *medial calcaneal rami* (Fig. 584) arise behind the medial malleolus and pass to the skin of the medial side of the heel and the neighboring part of the sole of the foot.

Both terminal branches of the tibial are mixed nerves for the innervation of the muscles and the skin of the sole of the foot, especially the skin of the toes. The medial plantar nerve is larger than the lateral and corresponds almost exactly to the median nerve of the hand, the lateral plantar, therefore, corresponding to the volar branch of the ulnar nerve of the hand.

4. The *medial plantar nerve* (Figs. 584 to 586) at first courses with the corresponding artery above the adductor hallucis (that is to say, covered by it), supplies it and the flexor digitorum brevis, and then continues onward in the medial plantar sulcus, from which it sends several cutaneous branches to the planta of the foot, and then passes above the flexor digitorum brevis to the toes. In so doing it gives off muscular rami for the flexor hallucis brevis and the two medial lumbricales and divides into its sensory terminal branches. These consist of the *medial* (*tibial*) *proper digital nerve of the hallux*, which separates early from the main stem, and of the three medial *common plantar digital nerves*, which course beneath the flexor digitorum profundus, at first alone and then in company with the corresponding plantar metatarsal arteries, to the

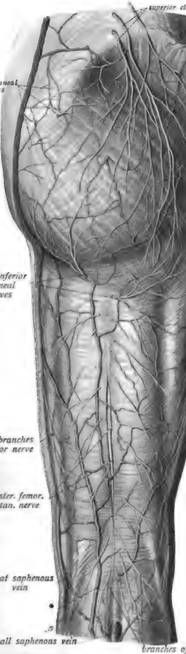

Fig. 719.

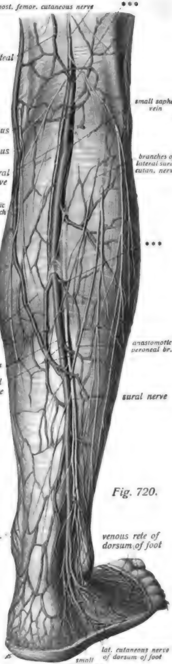

Fig. 720.

intervals between the four medial toes, and here each divides into two *proper plantar digital nerves.* Thus the medial plantar nerve, like the median nerve of the hand, gives off seven proper digital plantar nerves.

5. The *lateral plantar nerve* (Figs. 585 and 586) courses with and medial to the corresponding artery obliquely across the sole of the foot to the lateral plantar sulcus, lying between the quadratus plantæ, which it supplies, and the flexor digitorum brevis. In this part of its course it sends a few small, cutaneous branches to the planta and divides into its two terminal branches, which correspond to the respective branches of the volar ramus of the ulnar nerve. The purely sensory *superficial ramus* continues in the direction of the trunk and forms the *fourth common plantar digital* and the *lateral* (*fibular*) *proper digital nerve of the fifth digit*, the former dividing into the two corresponding *proper plantar digital nerves.* The *deep ramus* passes with the plantar arch (see page 75) into the depth of the sole and is almost purely motor. It supplies the abductor digiti V, the flexor brevis digiti V, the opponens digiti V, the adductor hallucis (oblique and transverse heads), the plantar and dorsal interossei, and the two lateral lumbricales.

(b) THE COMMON PERONEAL NERVE.

The *common peroneal* (*external popliteal*) *nerve* (Figs. 577, 580, 582, and 718) is formed by the division of the sciatic nerve at about the middle of the thigh. It is the weaker terminal branch, but, like the tibial, is a mixed nerve. At first it runs almost parallel to the tibial nerve, then passes along the medial border of the biceps femoris through the lateral part of the popliteal fossa, and then behind the lateral head of the gastrocnemius to the head of the fibula. Behind this it perforates the origin of the peroneus longus and divides into its two terminal branches the superficial and deep peroneal nerves. The branches of the common peroneal are:

1. In the thigh, *muscular rami* (Fig. 577) to the short head of the biceps.

2. The *lateral sural cutaneous nerve* comes from the trunk in the popliteal space, pierces the fascia, and ramifies in the skin of the calf and the lateral side of the leg down to the lateral malleolus. A strong branch forms the *peroneal anastomotic ramus*, which unites at the middle of the calf, at about the beginning of the tendon of Achilles, with the medial sural cutaneous nerve, to form the sural nerve.

3. The *superficial peroneal* (*musculocutaneous*) *nerve* (Figs. 582 and 721) passes out between the two heads of the peroneus longus, sends muscular rami to both peronei muscles, and courses down the leg, covered at first by the peroneus brevis, and in the lower third of the anterior surface of the leg pierces the crural fascia to terminate as the principal nerve of the dorsum of the foot, usually dividing into two branches. These are:

(*a*) The *medial dorsal cutaneous nerve*, which passes to the medial portion of the dorsum of the foot. It anastomoses with the saphenous nerve and supplies the skin of the dorsum of the foot, furnishes the *medial* (*tibial*) *dorsal digital nerve of the hallux*, and shares, in a variable manner with the following, the supply of the adjacent borders of the third to the fifth toes.

(*b*) The *intermediate dorsal cutaneous nerve* (Fig. 721) anastomoses with the lateral dorsal cutaneous, innervates the skin of the dorsum of the foot, and furnishes *dorsal digital nerves*, usually for the adjacent borders of the third and fourth, and fourth and fifth toes.

Thus the superficial peroneal supplies the medial border of the great toe, the lateral border

FIG. 721.—The superficial nerves and veins of the dorsum of the foot.
* Anastomosis with the deep veins of the dorsum of the foot.
FIG. 722.—A lateral view of the nerves and arteries of the second toe.
FIG. 723.—A lateral view of the nerves and vessels of the index finger.

of the second, both borders of the third and fourth, and the medial border of the fifth, the lateral border of the last being supplied by the sural nerve (see page 235), and the adjacent borders of the first and second toe by the deep peroneal nerve.*

4. The *deep peroneal* (*anterior tibial*) *nerve* (Figs. 582 and 583) is mainly motor. Together with the superficial peroneal it passes out between the two heads of the peroneus longus, then pierces the extensor digitorum longus and comes to lie in the crural interosseous space upon the anterior surface of the interosseous membrane, lateral to the anterior tibial artery. Like this it lies at first in the space between the extensor digitorum and tibialis anterior, then between the latter and the extensor hallucis. It gives off ***muscular rami*** to all three muscles, passes with their tendons beneath the cruciate ligament, gives off fine branches to the ankle-joint, and in the foot sends muscular rami to the extensores hallucis and digitorum brevis. The sensory terminal branch of the nerve accompanies the dorsal artery of the foot along the region of the first interosseous space, and after anastomosing with the medial dorsal cutaneous nerve, divides into two ***dorsal digital nerves*** for the lateral border of the great toe and the medial border of the second toe.*

REVIEW OF THE MOTOR AND SENSORY FUNCTIONS OF THE LUMBAR AND SACRAL PLEXUSES IN THE LOWER EXTREMITY.

Innervation of the Muscles.

I. Hip-muscles:

Iliopsoas = *lumbar plexus*. *Glutaeus maximus* = *inferior gluteal nerve* (*sacral plexus*). *Glutaeus medius, glutaeus minimus, tensor fasciæ latæ* = *superior gluteal nerve* (*sacral plexus*). *Obturator internus* (in part), *gemelli, quadratus femoris* = *sciatic nerve* † (*sacral plexus*).

II. Muscles of the thigh:

Extensor quadriceps cruris, sartorius, pectineus (largely) = *femoral nerve* (*lumbar plexus*). *Gracilis, adductor longus, pectineus* (partly), *adductor brevis, adductor magnus* and *minimus* (largely), *obturator internus* (partly), *obturator externus* = *obturator nerve* (*lumbar plexus*). *Semitendinosus, semimembranosus, long head of biceps, adductor magnus* (partly) = *tibial nerve* (*sacral plexus*). *Short head of the biceps* = *common peroneal nerve* (*sacral plexus*).

III. Muscles of the leg:

Triceps suræ, plantaris, popliteus, flexor digitorum longus, flexor hallucis longus, tibialis posterior = *tibial nerve* (*sacral plexus*). *Peroneus longus, peroneus brevis* = *superficial peroneal nerve* (*sacral plexus*). *Tibialis anterior, extensor hallucis longus, extensor digitorum longus* and *peroneus tertius* = *deep peroneal nerve* (*sacral plexus*).

IV. Muscles of the foot:

Dorsum of the foot: *Extensor hallucis brevis, extensor digitorum brevis* = *deep peroneal nerve* (*sacral plexus*).

Sole of the foot: *Flexor digitorum brevis, abductor hallucis, flexor hallucis brevis, two lumbricales* = *medial plantar nerve* (*sacral plexus*). *Quadratus plantæ, adductor hallucis, abductor digiti V, flexor brevis digiti V, opponens digiti V, dorsal interossei, plantar inteossei, two lumbricales* = *lateral plantar nerve* (*sacral plexus*).

* By its anastomosis with the medial dorsal cutaneous nerve the deep peroneal, if it be only poorly developed, may be excluded from both borders of these toes, the medial dorsal cutaneous replacing it.

† Or direct branches from the sacral plexus or inferior gluteal nerve.

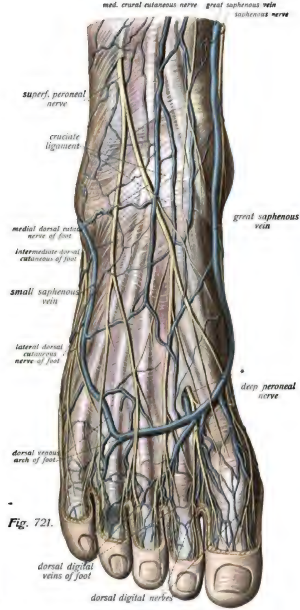

Fig. 721.

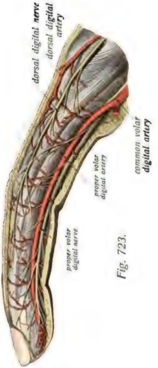

Fig. 723.

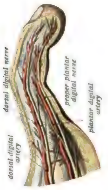

Fig. 722.

Innervation of the Skin Areas.

Subinguinal region = the *lumbo-inguinal nerve* (*lumbar plexus*). *Anterior femoral region* = *anterior cutaneous rami of the femoral nerve* and partly the *lateral femoral cutaneous nerve* (*lumbar plexus*). *Lateral femoral region* = *lateral femoral cutaneous nerve* (*lumbar plexus*). *Medial femoral region* = *anterior rami of the femoral nerve* (below) *cutaneous rami of the obturator* (*lumbar plexus*). *Gluteal region* (lower half) = *inferior cluneal nerves* (*sacral plexus*). *Posterior femoral region* = *posterior femoral cutaneous nerve* (*sacral plexus*). *Anterior region of the knee* = *anterior cutaneous rami of femoral nerve* and *infrapatellar ramus of the saphenous nerve* (*lumbar plexus*). *Posterior region of the knee* = *posterior femoral cutaneous nerve* (*sacral plexus*). *Anterior crural region* = *lateral sural cutaneous nerve* (*sacral plexus*) and *saphenous nerve* (*lumbar plexus*). *Lateral crural region* = *lateral sural cutaneous nerve* (*sacral plexus*). *Medial crural region* = *saphenous nerve* (*lumbar plexus*). *Posterior crural region* = *lateral* and *medial sural cutaneous nerves* (*sacral plexus*), partly also the *posterior femoral cutaneous nerve* (*sacral plexus*). *Dorsal region of the foot* = *saphenous nerve* (*lumbar plexus*), *medial*, *intermediate*, and *lateral dorsal cutaneous nerves* (*sacral plexus*). *Digital regions of dorsum of the foot* = in order, from the medial to the lateral border, the nerves are: 1. *Medial* (*tibial*) *dorsal digital nerve of hallux* from the *medial dorsal cutaneous nerve*. 2. *Lateral* (*fibular*) *dorsal digital nerve of the hallux* from the *deep peroneal nerve*. 3. *Medial* (*tibial*) *dorsal digital nerve of the second digit* from the *deep peroneal nerve*. 4. *Lateral* (*fibular*) *nerve of the second digit* from the *medial dorsal cutaneous nerve*. 5. *Medial* (*tibial*) *dorsal digital nerve of the third digit* from the *medial dorsal cutaneous nerve*. 6. *Lateral* (*fibular*) *dorsal digital nerve of the third digit* from the *intermediate dorsal cutaneous nerve*. 7. *Medial* (*tibial*) *dorsal digital nerve of the fourth digit* from the *intermediate dorsal cutaneous nerve*. 8. *Lateral* (*fibular*) *dorsal digital nerve of the fourth digit* from the *intermediate dorsal cutaneous nerve*. 9. *Medial* (*tibial*) *dorsal nerve of the fifth digit* from the *intermediate dorsal cutaneous nerve*. 10. *Lateral* (*fibular*) *dorsal digital nerve of the fifth digit* from the *lateral dorsal cutaneous nerve*. All dorsal nerves of the toes arise from the sacral plexus; the saphenous nerve (lumbar plexus) reaches only to the base of the great toe.

Calcaneal region = *tibial nerve* (*sacral plexus*) and *sural nerve* (*sacral plexus*). *Plantar region* = *tibial nerve* (*sacral plexus*). *Plantar digital region* = *medial* and *lateral plantar digital nerves* (*sacral plexus*). The first furnishes seven proper plantar digital nerves, the last, three. The middle eight arise by the forking of the four common plantar digital, the two marginal directly from the lateral and medial trunk respectively.

THE PUDENDAL PLEXUS.

The *pudendal plexus* (Figs. 568, 715, and 727) arises mainly from the anterior rami of the fourth and a part of the third, usually also from a small part of the second, sacral nerves. It is usually frequently and closely connected to the sacral plexus and lies on the posterior surface of the pelvis and the lower border of the piriformis. From it several nerves arise for the pelvic viscera and especially the pudendal nerve, and strong anastomoses connect the roots of the plexus with the sacral ganglion and the hypogastric plexus of the sympathetic nerve. The branches of the pudendal plexus are:

1. The *middle hemorrhoidal nerves* (Fig. 568) to that portion of the rectum which lies just above the floor of the pelvis. They unite with the sympathetic hypogastric plexus (see below).

2. The *inferior vesical nerves* pass to the base of the bladder; in the female, *vaginal nerves* pass to the vagina.

3. *Muscular rami* to the muscular floor of the pelvis, namely to the coccygeus and levator ani.

4. The main part of the pudendal plexus forms the *pudendal nerve* (Figs. 568, 724, and 725) which passes through the greater sciatic foramen, below the piriformis, accompanying the internal pudendal vessels and with them passing through the small sciatic foramen into the ischiorectal fossa. In its further course, and as regards its branches, it also corresponds to the internal pudendal artery. It terminates as the dorsal nerve of the penis in man and dorsal nerve of the clitoris in woman, and a sensory, cutaneous branch of the nerve usually pierces the sacrotuberous ligament and winds about the medial border of the gluteus maximus (near its origin) to the

FIG. 724.—The nerves and vessels of the male perineum.

Upon the left side, the superficial perineal musculature has been exposed and the ischiorectal fat removed; upon the right the transversus perinei superficialis has been divided, the urogenital diaphragm incised, and the ischiocavernosus drawn slightly to one side. * = Bifurcation of internal pudic artery into the perineal and penile arteries.

FIG. 725.—The nerves and vessels of the female perineum.

Upon the right side the bulbocavernosus has been partly removed and the vestibular bulb exposed, the transversus perinei superficialis divided, and the urogenital diaphragm incised. ** = The origin of the internal pudic vein from the vestibular bulb (vena bulbi vestibuli).

skin of the buttocks forming the *inferior medial cluneal nerve.* The remaining branches of the pudendal plexus arise in its course through the ischiorectal fossa and are:

1. The *inferior hemorrhoidal nerves* arise usually from the reticular first portion of the nerve and pass through the adipose tissue of the ischiorectal fossa to the external sphincter ani and to the skin of the anal region.

2. The *perineal nerve* represents the superficial terminal branch of the pudendal nerve. It traverses the ischiorectal fossa lying medial to the main stem and nearer to the perineal integument, and then passes, under cover of the superficial transverse perineal muscle, into the groove between the bulbocavernosus and ischiocavernosus. It is distributed to the skin of the anterior part of the anal region, and, together with the perineal rami of the posterior femoral cutaneous nerve, it supplies the skin of the perineum, the bulbocavernosus, the ischiocavernosus, the superficial, and in part the deep transverse perineal muscles, also the anterior portion of the external sphincter ani. It terminates in the *posterior scrotal* (*labial*) *nerves,* which supply the posterior half of the skin of the scrotum in the male, of the labia majora and the vestibule of the vagina in the female.*

3. The real (deep) terminal branch of the pudendal, the *dorsal nerve of the penis* (*clitoris*) (Figs. 568 and 571) accompanies in man the dorsal artery of the penis, and, lying laterally to it, passes forward along the dorsum of the organ to the glans penis, where it ramifies in the skin of the penis, the prepuce, and especially the glans. In the female the nerve is much smaller, but, as nerve of the clitoris, has a corresponding course.

THE COCCYGEAL PLEXUS.

The *coccygeal plexus* is by far the smallest plexus in the human body. It is made up mainly of the anterior rami of the fifth sacral and of the coccygeal nerves, and immediately succeeds the pudendal plexus, lying on either side of the lower end of the sacrum, on the sacrospinous ligament and coccygeus muscle. It receives sympathetic fibers from the lower sacral and the coccygeal ganglia of the sympathetic nerve, and gives origin to a few small nerves which are known as *anococcygeal nerves* and pass partly to the posterior portion of the levator ani, but mainly to the skin in the neighborhood of the coccyx (page 229).

THE SYMPATHETIC NERVOUS SYSTEM.

The sympathetic nervous system presents a distinct contrast to the cranial and spinal nerves, as well as to the whole central nervous system, in that it includes mainly the visceral and vascular

* Thus the posterior half of the external genitals is supplied by the pudendal plexus, the anterior by the lumbar plexus (ilio-inguinal nerve, page 230).

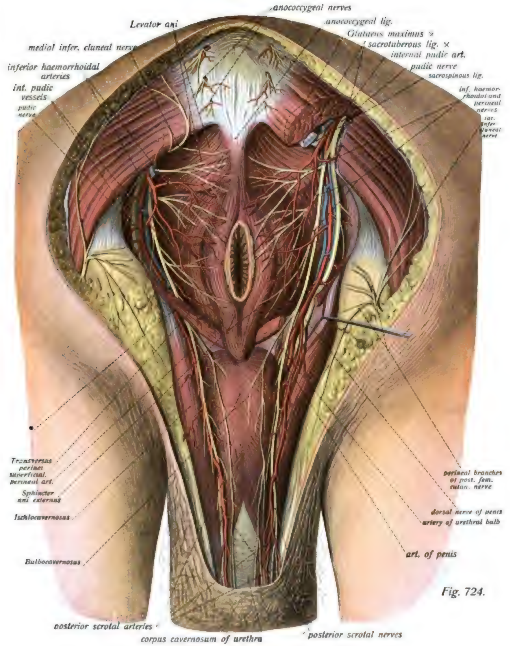
anococcygeal nerves
Levator ani
anococcygeal lig.
Glutaeus maximus ×
sacrotuberous lig. ×
medial infer. cluneal nerve
internal pudic art.
inferior haemorrhoidal arteries
pudic nerve
sacrospinous lig.
int. pudic vessels
inf. haemorrhoidal and perineal nerves
pudic nerve
lat. infer. cluneal nerve
Transversus perinei superficial.
perineal art.
Sphincter ani externus
Ischiocavernosus
Bulbocavernosus
perineal branches of post. fem. cutan. nerve
dorsal nerve of penis
artery of urethral bulb
art. of penis
posterior scrotal arteries
corpus cavernosum of urethra
posterior scrotal nerves

Fig. 724.

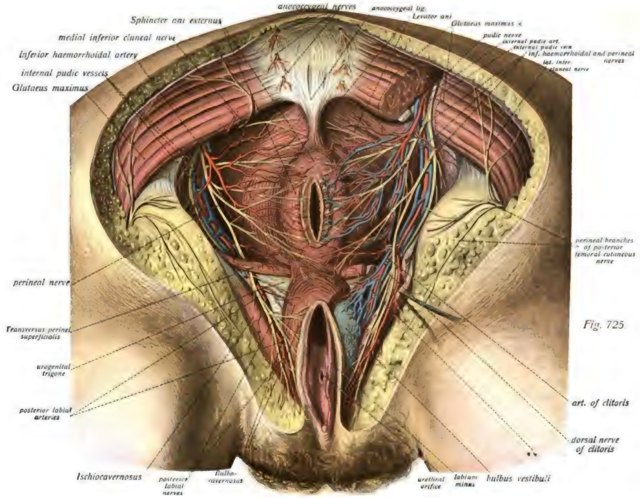
anococcygeal nerves
anococcygeal lig.
Levator ani
Glutaeus maximus ×
Sphincter ani externus
medial inferior cluneal nerve
inferior haemorrhoidal artery
internal pudic vessels
Glutaeus maximus
pudic nerve
internal pudic art.
internal pudic vein
inf. haemorrhoidal and perineal nerves
lat. infer. cluneal nerve
perineal branches of posterior femoral cutaneous nerve
perineal nerve
Transversus perinei superficialis
urogenital trigone
posterior labial arteries
art. of clitoris
dorsal nerve of clitoris
Ischiocavernosus
posterior labial nerves
Bulbo-cavernosus
urethral orifice
labium minus
bulbus vestibuli

Fig. 725.

nerves, and although it has manifold communications with the cerebrospinal system it represents, to a certain extent, an independent system. It is composed of a number of independent centers which form a chain on either side of the vertebral column, the successive centers being united by short nerve cords. The structure so formed is known as the *sympathetic trunk*, and the ganglia inserted in its course are the *ganglia of the sympathetic trunk* (Figs. 551, 693, 726, and 727).

The ganglia of the sympathetic trunk are connected with the neighboring cerebrospinal nerves by *rami communicantes*, through which the cerebrospinal nerves receive sympathetic fibers, and, conversely, cerebrospinal fibers enter the sympathetic nervous system, there being thus a mutual anastomosis.*

From the ganglia of the sympathetic trunk the branches of the sympathetic nervous system arise. They differ from those of the cerebrospinal system in many respects, being in the first place of a grayish-white color, not pure white like the latter,† since they consist mainly of nonmedullated nerve fibers, and furthermore, they rarely have a straight course and they form long branches. Much oftener, almost without exception, they form sympathetic plexuses which, especially in the region of the head, extend along the blood-vessels, and especially the arteries, cerebrospinal fibers having a part in the formation of the plexuses intended for the viscera of the thorax and abdomen. Imbedded in these sympathetic plexuses, especially the visceral ones, are numerous ganglia, some of which are very large and others microscopically small; they are known as *ganglia of the sympathetic plexuses* and again give rise to sympathetic fibers. Many small microscopic ganglia may also be found in the organs themselves (heart, eye, intestines).

The sympathetic fibers, like those of the cerebrospinal system, are partly motor and partly sensory, and the system supplies practically the entire nonstriated musculature of the body. ‡

THE SYMPATHETIC TRUNK.

The *sympathetic trunk* (Figs. 538, 587, 716, 726, and 727) is a paired structure resting upon the anterior (ventral) surface of the vertebral column, almost parallel to the median plane. Each trunk consists of a number of ganglia arranged at rather regular intervals, and united into a chain by usually short connecting cords. Since the sympathetic trunk ganglia develop as outgrowths from the spinal ganglia, the number of the former should typically agree with the latter, that is to say, a sympathetic trunk ganglion should occur at the level of each vertebra. Throughout the greater part of the trunk such an arrangement occurs, a marked deviation from it being found only in the neck, where several ganglia blend to form an especially large *superior cervical*

* [The fibers which pass from the cerebrospinal system to the sympathetic ganglia are medullated and form *white rami communicantes*, while those passing from the sympathetic ganglia to the cerebrospinal nerves are nonmedullated and are known as *gray rami communicantes*. The latter pass to the roots of practically all the spinal nerves, but the white rami are given off only by the thoracic and first and second lumbar and second and third or third and fourth sacral spinal nerves. The white rami fibers do not necessarily terminate in connection with the cells of the trunk ganglion with which they first come into connection, but may pass these and terminate in a higher or lower ganglion, or even in one of the ganglia of the sympathetic plexuses.—Ed.]

† Several sympathetic nerves, such as the greater splanchnic, have relatively numerous medullated fibers, and, therefore, resemble the cerebrospinal nerves in color.

‡ [It is probable that the sensory fibers contained in sympathetic nerves are really cerebrospinal fibers from the posterior root ganglia. The fibers which have their origin from the cells of the sympathetic ganglia are all nonmedullated and pass either to gland tissue or to nonstriped muscle (also to the heart musculature).—Ed.]

ganglion, which represents the upper end of the entire sympathetic trunk. The lower end of the trunk is formed by the *coccygeal ganglion*, situated at the level of the coccyx; it is very small, and in contrast to all the other ganglia of the trunk is unpaired, the trunks of the two sides uniting in it. In correspondence with the divisions of the vertebral column, *cervical*, *thoracic*, *lumbar*, *sacral*, and *coccygeal ganglia* may be recognized.*

Each trunk ganglion is connected to the spinal nerves by the communicating rami (see above). Similar relations also exist with the cerebral nerves, some of which have connections with the superior cervical ganglion.†

The sympathetic nerves may be divided into *cephalic*, *cervical*, *thoracic*, *abdominal*, and *pelvic portions*. The nerves of the cephalic portion have no independent centers, but arise from the upper end of the cervical part, and the abdominal and pelvic portions are intimately connected.

THE CEPHALIC AND CERVICAL PART OF THE SYMPATHETIC NERVOUS SYSTEM.

The cervical portion of the sympathetic trunk (Figs. 551 and 693) has only three ganglia; from these not only are the peripheral branches of the cervical portion of the system derived, but, from the superior one, also those of the cephalic portion.

1. The *superior cervical ganglion* is by far the largest trunk ganglion, and, with the exception of the cœliac ganglion of the abdominal portion of the system, is the largest sympathetic ganglion of the body. It is elongated, spindle-shaped, pointed above and below, and widest at its middle, but its width is scarcely one-third of its length, and it is situated behind the internal carotid and in front of the superior end of the longus capitis, at the level of the transverse processes of the first to the third cervical vertebræ. From its upper end the *internal carotid nerve* arises, the principal nerve of the cephalic portion of the sympathetic system, while its lower end gives origin to a long, communicating branch to the middle cervical ganglion.

The *middle cervical ganglion* is always much smaller than the superior, but is usually constant. However, it is sometimes entirely absent and is much more variable in its relations than the other two. It is of a round or oval shape and is situated at the level of the sixth or seventh cervical vertebra, somewhat distant, therefore, from the superior ganglion, and at the upper or lower border of the thyreocervical trunk or the inferior thyreoid artery itself, generally a little above the highest point of the arch of the subclavian artery.

The *inferior cervical ganglion* is usually larger than the medial one, often even double its size, and of a flattened oval shape. It lies behind the subclavian artery close to the origin of the vertebral artery, just above the first thoracic ganglion, with which it frequently blends to form a single large ganglion. With respect to the vertebral column it lies in such a position as to correspond to the transverse process of the seventh cervical vertebra and the neck of the first rib.

That part of the sympathetic trunk which is not ganglionic and unites the three cervical ganglia is a round, but rather thin, nerve cord lying in front of the longus colli and the prevertebral

* The number of sympathetic ganglia is not quite constant. Sometimes an accessory ganglion occurs, or a normal one may be divided into two parts.

† [Certain ganglia in the head region, such as the ciliary, sphenopalatine, otic, and submaxillary, must be regarded as sympathetic ganglia, and some of the fibers passing to them from the cerebral nerves, such as the chorda tympani fibers passing to the submaxillary ganglion, must be regarded as equivalent to white rami fibers.—ED.]

lamina of the cervical fascia, behind the large cervical vessels, especially the common or internal carotid artery, according to the level at which it is examined. That part which unites the two lower ganglia, which are quite close to one another, is very short and divides into two parts, which surround the subclavian artery. The posterior part is shorter and thicker than the anterior one and passes from the middle ganglion downward and backward to the inferior ganglion, which lies at a somewhat deeper level. The anterior part is thin and much longer than the posterior; it passes in front of the subclavian artery, winds around its anterior inferior surface, and behind it, again ascends to the inferior cervical ganglion. The delicate loop by which the subclavian is thus surrounded is termed the *subclavian ansa* (ansa of Vieussens) (Fig. 726).

THE PERIPHERAL BRANCHES OF THE CEPHALIC AND CERVICAL PORTIONS.

From the **superior cervical ganglion** arise:

1. Rami communicantes (gray) to the first, second, third, and occasionally also to the fourth cervical nerves, and branches to the hypoglossal.

2. The *jugular nerve* (Fig. 693), a communication between the ganglion and the ganglion nodosum of the vagus and the petrosal ganglion of the glossopharyngeal. Both branches may have independent courses.

3. The *internal carotid nerve* (Figs. 693, 685, and 689) arises from the upper pointed end of the ganglion and represents the direct continuation of the sympathetic trunk to the head. Passing along the posterior medial surface of the internal carotid artery it passes into the carotid canal and forms the important internal carotid plexus (see below).

4. The *external carotid nerves* are several delicate fibers which form the much weaker external carotid plexus.

5. The *laryngopharyngeal rami* (Fig. 693), the majority of which arise as relatively strong branches from the superior cervical ganglion, together with the vagus and glossopharyngeal nerves, form the pharyngeal plexus. Several branches may also pass with the superior laryngeal nerve to the larnyx, while others form the small *ascending pharyngeal plexus* along the ascending pharyngeal artery.

6. The *superior cardiac nerve* (Fig. 693) arises from the inferior border of the superior ganglion and for a short distance accompanies the sympathetic trunk itself, lying medial to it. Often it divides into several anastomosing branches. It unites with the cardiac branches of the vagus and helps to form the cardiac plexus.

From the **middle cervical ganglion** arise:

1. The *middle cardiac nerve* (Fig. 693), which consists of several reticularly connected fibers, and passes down the medial posterior surface of the subclavian artery (on the right side the innominate artery) to the arch of the aorta, and ends in the cardiac plexus.

2. Fine branches to the common carotid plexus.

3. Rami communicantes (gray) (Fig. 726) to the fourth, fifth, and sixth cervical nerves.

From the **inferior cervical ganglion** arise:

1. Rami communicantes (gray) to the sixth to the eighth cervical nerves and partly also to the first thoracic nerve.

2. The *inferior cardiac nerve* is usually strengthened by a branch from the first thoracic

ganglion (the lowest cardiac nerve), and is connected with the middle cardiac nerve, as well as with the cardiac branch of the recurrent nerve, and together with them passes to the cardiac plexus (see below).

3. Delicate branches to the subclavian plexus (see below).

THE PLEXUSES OF THE CEPHALIC AND CERVICAL PORTIONS.

1. The **internal carotid plexus** (Figs. 679, 685, and 689), in the form of a wide-meshed plexus, surrounds the internal carotid artery in its course through the carotid canal and the cavernous sinus, the part lying in the sinus being somewhat narrower meshed and known as the *cavernous plexus*. During the course of the plexus an occasional small ganglion is inserted (carotid ganglion). From the plexus branches arise which communicate with the cerebral nerves and also a number of other smaller plexuses of the head. These branches and plexuses are:

(*a*) The *superior* and *inferior caroticotympanic nerves*, which pass to the tympanic plexus (page 207).

(*b*) The *deep petrosal nerve*, which passes to the sphenopalatine ganglion (see page 200).

(*c*) Fine branches to the semilunar ganglion of the trigeminus.

(*d*) Communicating branches to the abducens, often also to the oculomotor.

(*e*) Plexuses which accompany the cerebral vessels (*plexuses of the anterior cerebral, the middle cerebral*, and *chorioidal arteries*).

(*f*) The *ophthalmic plexus*, which penetrates into the orbit along the ophthalmic artery.

(*g*) The *sympathetic roots of the ciliary ganglion* (page 198), which pass partly independently and partly with the nasociliary nerve to the ganglion, and conduct to it, among other fibers, the motor fibers for the dilator of the pupil (see "Special Sense Organs").

2. The **external carotid plexus** is much weaker than the internal. It is formed by the external carotid nerves and surrounds the artery in the form of a very fine plexus, being also continued along the majority of its branches and giving off branches to the carotid glomus. It thus gives rise to the following: A *superior thyreoid plexus*, a *lingual plexus*, an *external maxillary plexus* with the *sympathetic root of the submaxillary ganglion* (page 203), an *occipital plexus*, a *posterior auricular plexus*, a *superficial temporal plexus*, an *internal maxillary plexus*, which gives rise to the *meningeal plexus*, and the *sympathetic root of the otic ganglion*.

3. The **common carotid plexus** consists of only a few fibers coming from the middle ganglion and furnishes vascular branches to the artery.

4. The **subclavian plexus** consists of delicate fibers from the inferior ganglion and is continued as the *internal mammary, inferior thyreoid*, and *vertebral plexuses* along the main branches of the artery.

THORACIC PORTION OF THE SYMPATHETIC NERVOUS SYSTEM.

The *thoracic portion of the sympathetic trunk* (Figs. 538, 587, and 726) forms a chain of from eleven to twelve *thoracic ganglia*, which are connected by short, often double, nerve cords. These course in front of the intercostal vessels and nerves, thus bridging the posterior part of the intercostal space. The uppermost thoracic ganglion is united by a very short portion of the trunk with the inferior cervical ganglion; the lowest with the first lumbar ganglion.

The thoracic part of the sympathetic trunk is situated, with its ganglia, in front of the heads of the ribs and is covered only by the endothoracic fascia and costal pleura. At the level of the head of each rib* a ganglion occurs. The two lower ganglia are also covered by the lumbar portion of the diaphragm, so that the communicating ramus to the first lumbar ganglion must pass through its intermediate and lateral crura. The upper and lower thoracic ganglia are larger than the middle ones, but smaller than the superior and also than the inferior cervical ganglion. Their shape is oval or triangular, and usually flattened. Besides (large) communicating rami to the intercostal nerves and delicate branches to the aortic plexus, two large visceral nerves arise from the thoracic portion of the sympathetic trunk, which unite the sympathetic trunks of the two sides while passing downward in front of the vertebral column, and are among the strongest peripheral branches of this system; they are known as the splanchnic nerves.

1. The *greater splanchnic nerve* (Figs. 538, 587, and 726) arises by several roots from the fifth or sixth to the ninth or tenth thoracic ganglion, turns medially and downward, coursing across the lateral surfaces of the bodies of the lower thoracic vertebræ, and passes through the diaphragm between the medial and intermediate crura of the lumbar portion, and, therefore, medial to the sympathetic trunk. In the abdominal cavity it terminates in the cœliac plexus. A ganglion which may occur in the course of the relatively strong and white† nerve is called *splanchnic ganglion.*

2. The *lesser splanchnic nerve* arises from the two lowest thoracic ganglia, courses parallel with the major, but lateral to it, pierces the diaphragm, and passes partly to the cœliac ganglion, but also by its *renal ramus* to the renal plexus.‡

In addition two plexuses occur in the thoracic cavity, one of which is formed entirely by the sympathetic system and the other in large part.§

1. The *thoracic aortic plexus* is a fine, weak plexus which surrounds the thoracic aorta and passes with it through the aortic hiatus into the abdominal cavity. Here it becomes continuous with the abdominal aortic plexus.

2. The *cardiac plexus* is formed by the sympathetic system together with the vagus nerve. It is a wide-meshed plexus which surrounds the arch of the aorta, the ascending aorta, and the pulmonary artery, and, in addition to smaller ganglia, possesses a larger, constant *cardiac ganglion* (the ganglion of Wrisberg), which lies between the point of division of the pulmonary artery and the arch of the aorta.

The cardiac plexus is formed: 1. From the vagus‖ of either side, by the cardiac branches (see page 209) which originate partly from the trunk of the vagus, partly (the majority) from

* If the number of ganglia is less than twelve, as is often the case (eleven, more rarely ten or nine), a ganglion does not correspond with the head of each rib, but either one or more of them lie in the intervals between successive ribs.

† The greater splanchnic nerve is whiter than the sympathetic trunk, since it contains a greater number of medullated fibers.

‡ Occasionally the renal ramus is independent and forms a small, third splanchnic nerve, the least splanchnic nerve.

§ In contrast to the cardiac plexus the pulmonary plexus is formed almost completely by the vagus (see page 210), although a few sympathetic pulmonary branches take part.

‖ Also the inferior end of the descending branch of the hypoglossal (see page 212) occasionally takes part in the formation of the plexus.

FIG. 726.—The thoracic portion of the sympathetic trunk and the thoracic and abdominal portions of the vagus nerve.

The anterior thoracic wall has been removed by a frontal section, the veins have been cut away, and the only arteries left are the aorta and some of its branches. All the thoracic viscera have been removed; of the abdominal viscera, only the stomach has been left *in situ*.

FIG. 727.—The abdominal and pelvic portions of the sympathetic trunk.

The anterior abdominal and pelvic walls have been removed, the lumbar plexus exposed by removal of the psoas major, and the aorta left *in situ* up to its bifurcation. * — Visceral branches of the pudendal plexus.

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its laryngeal branches. 2. From the sympathetic system of either side by the superior, middle, and inferior cardiac nerves of the cervical trunk ganglia.

From the cardiac plexus numerous nerves arise for the heart wall and penetrate it partly independently, partly by way of the *anterior* and *posterior coronary plexuses,* which extend along the corresponding arteries.

THE ABDOMINAL AND PELVIC PORTIONS OF THE SYMPATHETIC NERVOUS SYSTEM.

The abdominal and pelvic portions (Figs. 568, 716, and 727) are distinguished by the extensive and strong plexuses which here represent the peripheral part of the sympathetic system, and in comparison with which the sympathetic trunk becomes insignificant.

The *sympathetic trunk* of the abdominal cavity and pelvis includes the four or five *lumbar ganglia*, four (to five) *sacral ganglia*, and the unpaired *coccygeal ganglion.*

The *lumbar ganglia* (Figs. 716 and 727) are smaller than the thoracic (especially than the lower ones), and lie on the medial border of the psoas major muscle, thus relatively much nearer to the middle line than the thoracic ganglia. On the right side they are more or less covered by the inferior vena cava, and in the left they lie along the left border of the abdominal aorta. The connecting cords between the successive ganglia are a little longer and thinner than those of the thoracic region. The ganglia are connected with the corresponding lumbar nerves by *rami communicantes*, and the ganglia of either side are also connected by oblique transverse branches which pass behind the aorta and inferior vena cava. In addition branches from the lumbar ganglia pass to the large plexuses of the abdominal cavity.

The *sacral ganglia* (Figs. 568 and 727) are about equal in size to the lumbar, but diminish from above downward. They lie in front of the pelvic surface of the sacral bone, medial to the anterior sacral foramina, so that the nerves of the two sides converge below, both trunks finally uniting in the unpaired coccygeal ganglion. They are connected by relatively thin portions of the trunk, and here the trunks and ganglia of either side anastomose by transverse branches to a much greater extent than do the lumbar ganglia. In addition the sacral ganglia give rami communicantes to the anterior branches of the sacral nerves and are connected with the hypogastric plexus.

The *coccygeal ganglion* (Fig. 727) is unpaired, and is usually very small or replaced by a small plexus. Through its communicating rami it anastomoses with the fifth sacral and the coccygeal nerve.

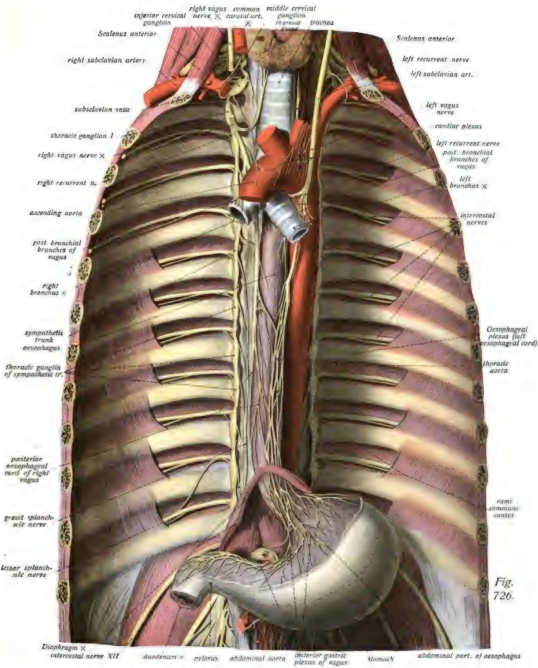
inferior cervical ganglion
right vagus nerve ×
common carotid art. ×
middle cervical ganglion
thyreoid gland
trachea
Scalenus anterior
right subclavian artery
subclavian ansa
thoracic ganglion I
right vagus nerve ×
right recurrent n.
ascending aorta
post. bronchial branches of vagus
right bronchus ×
sympathetic trunk
oesophagus
thoracic ganglia of sympathetic tr.
posterior oesophageal cord of right vagus
great splanchnic nerve
lesser splanchnic nerve
Diaphragm ×
intercostal nerve XII
Scalenus anterior
left recurrent nerve
left subclavian art.
left vagus nerve
cardiac plexus
left recurrent nerve
post. bronchial branches of vagus
left bronchus ×
intercostal nerves
Oesophageal plexus (left oesophageal cord)
thoracic aorta
rami communicantes
duodenum ×
pylorus
abdominal aorta
anterior gastric plexus of vagus
stomach
abdominal port. of oesophagus

Fig. 726.

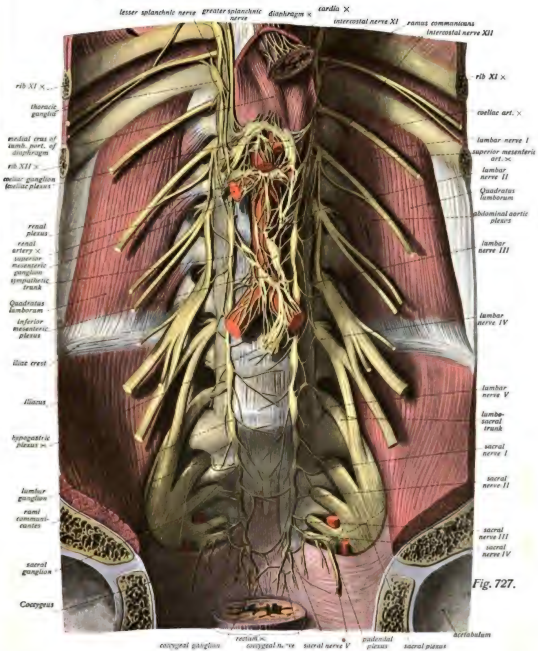
lesser splanchnic nerve
greater splanchnic nerve
diaphragm ×
cardia ×
intercostal nerve XI
ramus communicans
intercostal nerve XII
rib XI ×
thoracic ganglia
medial crus of lumb. port. of diaphragm
rib XII ×
coeliac ganglion (coeliac plexus
renal plexus
renal artery ×
superior mesenteric ganglion
sympathetic trunk
Quadratus lumborum
inferior mesenteric plexus
iliac crest
iliacus
hypogastric plexus ×
lumbar ganglion
rami communicantes
sacral ganglion
Coccygeus
rib XI ×
coeliac art. ×
lumbar nerve I
superior mesenteric art. ×
lumbar nerve II
Quadratus lumborum
abdominal aortic plexus
lumbar nerve III
lumbar nerve IV
lumbar nerve V
lumbo-sacral trunk
sacral nerve I
sacral nerve II
sacral nerve III
sacral nerve IV
acetabulum
rectum ×
coccygeal ganglion
coccygeal nerve
sacral nerve V
pudendal plexus
sacral plexus

Fig. 727.

THE SYMPATHETIC PLEXUSES OF THE ABDOMINAL CAVITY.

1. The **abdominal aortic plexus** (Fig. 727) is a wide-meshed plexus lying on the abdominal aorta and is connected with the other main plexuses of the abdomen. Below, at the bifurcation of the aorta, it passes into the hypogastric plexus.

2. The **cœliac plexus** (Fig. 727) is the largest sympathetic plexus of the body and consists mainly of two large, semilunar *cœliac ganglia* which lie one on either side of the abdominal aorta at the level of the origin of the cœliac artery. They are connected by numerous transverse anastomosing branches which form the cœliac plexus, this surrounding the origin of the cœliac artery and extending down to the root of the superior mesenteric artery and laterally to the middle crura of the lumbar portion of the diaphragm. The inferior part of the plexus usually has an additional unpaired ganglion, lying at the root of the superior mesenteric artery, and known as the *superior mesenteric ganglion*. The splanchnic nerves enter the cœliac plexus, the greater entirely and the lesser partly, and sympathetic fibers pass to it from the thoracic aortic plexus, vagus fibers from the œsophageal and gastric plexuses, and phrenic fibers from the phrenico-abdominal nerves. From the plexus numerous fibers pass out in all directions and communicate with almost all the other plexuses of the abdominal cavity; for the most part, however, they form further plexuses. These are:

(*a*) The *phrenic plexus*, paired, along the inferior phrenic artery, contains a few small phrenic ganglia.

(*b*) The *superior gastric plexus*, unpaired, ramifies from the lesser curvature to the anterior and posterior surface of the stomach and unites with the two gastric plexuses of the vagus (page 211).

(*c*) The *hepatic plexus*, also unpaired, passes along the hepatic artery to the liver, anastomoses with the superior gastric plexus and divides at the portal fissure of the liver into a right and left hepatic plexus, whose branches penetrate into the liver with the arterial branches and also pass to the gall-bladder, the ligamentum teres and the ligament of the ductus venosus. Furthermore, branches of the hepatic plexus pass along the greater curvature of the stomach with the right gastro-epiploic artery to the stomach wall and form—

(*d*) The *inferior gastric plexus*.

(*e*) The *splenic plexus* passes with the corresponding artery to the pancreas, the fundus of the stomach, and the spleen.

3. The *suprarenal plexus* is strong and paired, and extends to the hilus of the suprarenal body and forms small (microscopic) ganglia within the organ.

4. The *renal plexus* lies at the origin of each renal artery from the abdominal aorta, and is, therefore, also paired. It communicates with the cœliac and superior mesenteric plexuses and receives the renal branch of the lesser splanchnic nerve. Its branches penetrate with the arteries into the kidneys.

5. The *internal spermatic plexus* accompanies the corresponding artery, and in the male terminates in the scrotum, in the female in the ovary (plexus of the ovarian artery).

6. The *superior mesenteric plexus* is strong and unpaired. It arises from the lower end of the cœliac plexus and really represents its direct continuation. It furnishes almost all branches to the intestinal canal, these ramifying along the corresponding artery and its branches, and forming with the vagus the *myenteric* and *submucous plexuses*, especially the latter.

7. The *inferior mesenteric plexus* is also unpaired and passes almost insensibly into the unpaired part of the following plexus. It sends its rami along the corresponding artery and its branches to the descending colon and rectum. The ***superior hemorrhoidal nerves*** to the latter form the unpaired ***superior hemorrhoidal plexus.***

8. The **hypogastric plexus**, the large sympathetic plexus of the pelvis, is unpaired at its origin and lies in front of the fifth lumbar vertebra and the promontory in the form of a strong elongated plexus. From this the paired plexuses for the lower extremities arise and also paired portions of the plexuses which pass along the hypogastric artery on either side into the true pelvis.

The plexuses to the limbs are known as the *iliac plexuses.* They accompany the common iliac and external iliac arteries, are but feebly developed, and are continued downward as the *femoral* and *popliteal plexuses* along the arterial trunks.

The pelvic part of the hypogastric plexus (Figs. 568 and 727) is strengthened by fibers from the sacral ganglia of the sympathetic trunk and also receives numerous cerebrospinal branches from the pudendal plexus. It lies beside the rectum upon the pelvic surface of the levator ani, close to the vagina in the female and on the fundus of the bladder in the male. Together with the fibers from the pudendal plexus it forms a number of smaller plexuses:

(*a*) The *middle hemorrhoidal plexus* on the rectum.

(*b*) The *prostatic plexus* on the prostate.

(*c*) The *deferential plexus* on the ampulla of the vas deferens and the seminal vesicles.

(*d*) In the female, the large *uterovaginal plexus*, especially well developed on the lateral border of the cervix uteri, where it contains some constant ganglia.

(*e*) The *vesical plexus* on the bladder.

(*f*) The *cavernous plexus of the penis* (*clitoris*) which forms the terminal part of the hypogastric plexus. It lies at the root of the penis (clitoris) and sends the *major cavernous nerve* and the *minor cavernous nerves of the penis* (*clitoris*) to the corpus cavernosum, where they course in company with the deep vessels of the penis (clitoris). They are principally of sympathetic origin, while the dorsal nerves of the penis are of spinal origin.

THE SENSE ORGANS.

THE VISUAL ORGAN OR EYE.

THE main constituent of the organ of sight is the eyeball with the optic nerve; it represents the true organ of vision. To it are added the accessory visual organs, serving partly as a motor apparatus, partly as protective organs.

THE EYEBALL.

The *eyeball* (*bulbus oculi*) (Figs. 728 and 731) is an almost spherical body situated in the orbital cavity, whose anterior end is formed by a segment of a sphere with a smaller radius, while at the posterior end the optic nerve is attached, forming, as it were, a stalk for the eyeball. The eyeball is not completely contained in the orbit, but projects considerably beyond the lateral portion of the orbital opening, so much so that its equator is only slightly behind the lateral border of the orbit. On the other hand, the superior, inferior, and, for the most part, the medial surfaces * of the bulb are protected by the bony orbital cavity, the vertical diameter of the orbital opening passing just in front of the most prominent part of the cornea, while the horizontal diameter is behind it. Nor does the eyeball nearly fill the orbital cavity. The posterior pole lies at about the middle of the length of the orbit, so that the eyeball occupies only its anterior, more spacious half, and is surrounded not only by its muscles and fascia, but also with a rich cushion of adipose tissue, the *adipose body of the orbit*. The long axis of the eyeball does not exactly coincide with that of the orbital cavity, but lies somewhat lateral to it; the same is true of the relative positions of the center of the orbit and of that of the eye.

The shape of the eyeball varies, though only slightly, from the sphere and approaches that of an ellipsoid. Its largest diameter is diagonal (from medially and above laterally and downward). The anterior extremity is known as the *anterior pole*, the posterior one as *posterior pole*, the former corresponding to the point of greatest curvature of the cornea, the latter to a point close to the central fovea of the retina (see below). The line connecting the two poles is the *axis*, and it is convenient to make a distinction between an *external ocular axis*, which is considered to pass from the vertex of the cornea to the point on the external coat of the eye which corresponds to the posterior pole, and an *internal ocular axis*, which unites the posterior plane of the corneal surface with the inner surface of the retina at the point corresponding to the posterior pole. The length of the external axis averages 24 mm., that of the internal 21.78 mm.

The *optical axis* differs somewhat from the anatomical axis of the eye.† It extends from the vertex of the cornea to the floor of the central fovea and crosses the axis of the eye at a very acute angle, while the latter makes an angle of about 20° with a line which represents a prolongation of the optic nerve.

* These relations differ in individuals, partly also very markedly in different races, and under certain conditions also to a slight extent on the two sides in the same person.

† The physiological conception of the line of vision is to be distinguished from the optical axis.

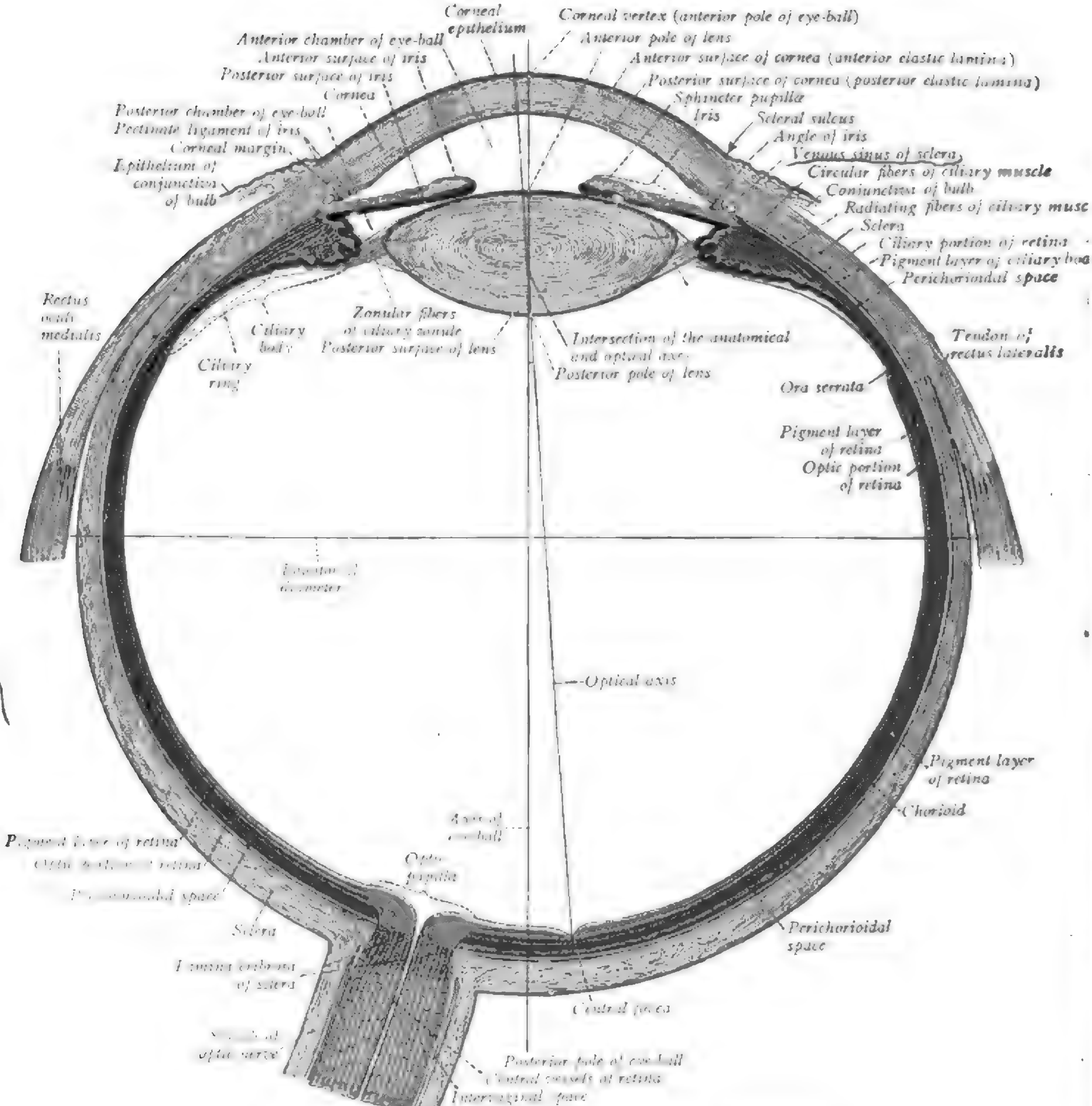

FIG. 728.—A meridional section of the human eye-ball (diagrammatic).
The inner tunic is blue; the middle tunic red.

The transverse diameter of the eyeball is of about the same size as the axis (24 mm.), and connects the nasal surface with the temporal surface at the line of greatest width, while the vertical diameter is smaller, being only 23.5 mm.*

The eyeball is formed mainly by three concentric coats, which are curved in correspondence with the external form of the ball. They surround the transparent, partly fluid, partly compact contents of the eyeball, and are known as the external *fibrous tunic*, the middle or *vascular tunic* and the internal tunic or *retina*.

THE FIBROUS TUNIC OF THE EYE.

The fibrous tunic is by far the largest of the three coats, and is decidedly the firmest. It encloses the whole eyeball like a capsule, and is divided into an anterior, smaller, transparent, more curved portion, the *cornea*, and a larger, posterior, opaque portion, the *sclera*, about five-sixths of the circumference being formed by the latter and one-sixth by the cornea.

The Sclera.—The sclera (Figs. 728 to 731, and 733 to 735) is a firm, thick fibrous coat, composed of interlacing bundles of connective tissue, and has a white color. In its posterior medial portion it is very intimately connected with the dural sheath of the optic nerve, anteriorly it is quite sharply marked off from the cornea, although in reality it is directly continuous with the tissue of the latter. It is thicker in the posterior portion of the eyeball than at the equator, in front of which it again thickens, being strengthened by the recti muscles that are inserted here.† It becomes continuous with the cornea, either by forming a sort of groove (*corneal rima*) for the reception of the corneal border or it merely overlaps the cornea externally. The *scleral sulcus* is the groove on the anterior surface of the eyeball which indicates the junction of sclera and cornea, and corresponding to it, near its posterior surface and still in the region of the sclera, is a ring-like vein or a simple circular plexus, the so-called *canal of Schlemm* or the *scleral venous sinus.*

On its posterior surface, on the nasal side of the axis, the sclera is pierced by the bundles of the optic nerve, which produce a cribriform area in the sclera, the *lamina cribrosa of the sclera.* In addition the sclera is perforated obliquely at various points of its surfaces by the ciliary nerves and vessels entering the eyeball.

The sclera is very poorly supplied with vessels. Its inner surface is very smooth and is connected with the middle tunic by a thin layer of very delicate, loose, pigmented tissue, known as the *lamina fusca.* Connected with the rougher outer surface, in addition to the sheath of the optic nerve, there are also the tendons of the six muscles of the eye, as well as the episcleral connective-tissue layer of the conjunctiva (see page 273).

The Cornea.—The cornea is a transparent structure, shaped somewhat like a watch-crystal and curved more strongly than the sclera. It forms the anterior sixth of the eyeball and is not exactly circular in outline, but is a little broader in its horizontal than in its vertical diameter.‡ In looking at it from in front it seems transversely elliptic, but from behind it is exactly circular,

* The medial surface of the eye, that nearest the nose, is known as the nasal surface, that nearest the temple as the temporal surface.

† The greatest thickness of the sclera (posteriorly) is 1 mm.; the least (behind the tendons of the recti muscles) 0.3 to 0.4 mm.; the mean (behind the equator and at the line of the insertion of the recti muscles) 0.6 mm.

‡ The vertical diameter of the cornea averages 11 mm., the horizontal 11.8 mm.

FIG. 729.—The right eyeball of the human subject divided in half by a meridian section. (Enlarged five times.)

The vitreous body has been removed. n = Nasal, t = temporal.

FIG. 730.—The left eyeball of a four-year-old child divided in half by a meridian section, showing a well-developed hyaloid canal and the remains of hyaloid vessels.

A portion of the vitreous body has been removed on the nasal side. n = Nasal, t = temporal. * = Remains of the hyaloid vessels.

FIG. 731.—The middle tunic of the eye exposed by meridian sections of the outer tunic. (Enlarged four times.)

* = Cut margin of pectinate ligament.

FIG. 732.—The anterior aspect of the middle tunic of the eye after complete removal of the outer tunic. (Enlarged five times.)

** = Cut margin of the cornea.

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this appearance being due to the fact that on the anterior surface of the eyeball the border of the sclera covers the cornea a little more above and below than at the sides.

The surfaces of the cornea are known as the *anterior surface*, which is convex, and the *posterior surface*, which is concave. The center, the point of greatest curvature, is the *corneal vertex*, and the periphery, which is embraced by the sclera in the region of the corneal rima, the *corneal limbus*. The cornea is not noticeably thicker than the sclera, but it is thicker at the periphery than at the middle.*

Both corneal surfaces are free, the anterior facing the conjunctival space, the posterior bounding the anterior chamber of the eye. The true corneal substance or *substantia propria* is in direct continuity with the scleral tissue; its anterior surface is covered by an *anterior elastic lamina* (Bowman's membrane), the posterior by a *posterior elastic lamina* (Descemet's membrane); upon the latter rests the *endothelium of the anterior chamber* and upon the former the *corneal epithelium*, which is directly continuous with the conjunctival epithelium. At the junction of the conjunctiva with the periphery of the cornea a narrow ring, the *conjunctival annulus*, is formed.

The cornea is completely devoid of blood-vessels, but marginal loops pass a short distance (about 1 mm.) into the substantia propria. It is, however, exceedingly well supplied with nerves, which extend into the epithelium.†

THE VASCULAR TUNIC.‡

The vascular tunic is a delicate, pigmented, soft coat, which contains the vessels and (internal) muscles of the eye. It is divided into three parts: a posterior part, lying close to the sclera, but separated from it by the lamina fusca, is the *chorioid*, which is perforated at the point of entrance of the optic nerve; an anterior part, the *iris*, has the shape of a diaphragm with a central, round opening, the pupil, and is separated from the cornea by the *anterior chamber* of the eye; and a middle, thickened part is the *ciliary body*, which, at the corneal rima, is in close connection with the sclera by means of a ring-shaped thickening, the *ciliary annulus*.

The Chorioid.—The chorioid (Figs. 728 to 734) is a thin coat, 0.5 to 0.8 mm. in thickness, rich in pigment and blood-vessels, whose smooth inner surface faces the retina and the outer

* The thickness at the middle is 0.8 to 0.9 mm., at the periphery 1.1 mm.

† For details see the Sobotta-Huber *Atlas and Epitome of Histology*.

‡ Also called middle tunic or uvea.

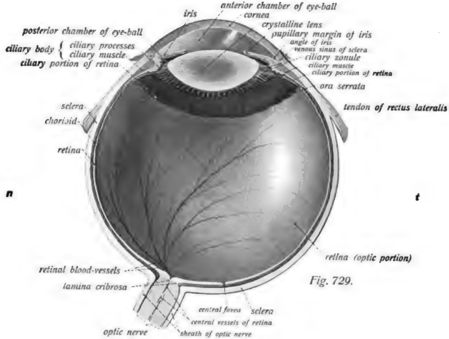

Fig. 729.

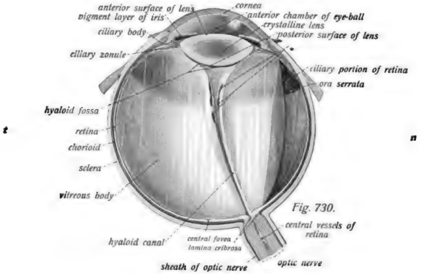

Fig. 730.

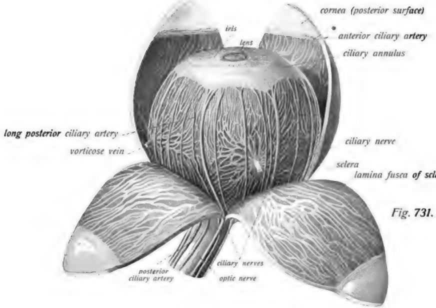

Fig. 731.

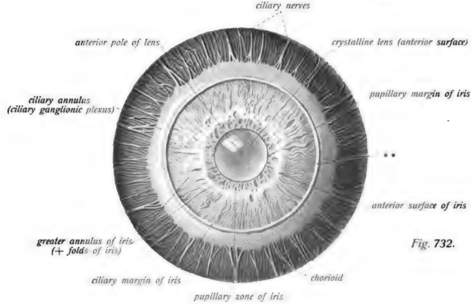

Fig. 732.

surface the sclera. It is separated from the latter by a very narrow space, the *perichorioidal space*, which is traversed, however, by vessels and nerves which penetrate through the sclera; so that the outer surface of the chorioid seems rough after its removal on account of the broken vessels. The chorioid is of a brownish color, the intensity of which depends upon the general development of pigment (in the hair, etc.) of each individual, and upon its outer surface are the larger vessels and nerve stems, which run, for the most part, in a meridional direction and forward, and the collecting vorticose veins, formed by the union of venous branches arranged in a radiating manner (Fig. 744). That layer of the chorioid in which we find the larger vessels and nerve stems is known as the *lamina vasculosa;* it does not immediately adjoin the lamina fusca of the sclera or the perichorioidal space, but is separated from it by a thin connective-tissue stratum, which is also pigmented and is known as the *suprachorioidal lamina.* Internal to the lamina vasculosa is the *choriocapillary lamina,* which contains the ramifications of the smaller vessels and is separated from the retina by a fine, elastic membrane, the *basal lamina* (Bruch's membrane). At the point where the optic nerve pierces the tunics of the eye the chorioid is perforated (the optic foramen of the chorioid), and the margins of the perforation being united to the connective tissue surrounding the optic nerve, as well as also to the sclera, the chorioid and sclera are fused at this point.* Anteriorly, the chorioid passes without demarcation into the ciliary body.

The Ciliary Body.—The ciliary body (Figs. 733, 735, and 736) is a circular thickening of the vascular tunic. Posteriorly it passes into the chorioid without presenting any distinct line of junction, while anteriorly the outer border of the iris arises from it. It consists of the *ciliary muscle* on the one hand and the *ciliary corona* and *orbiculus ciliaris* on the other. The *ciliary muscle* is a circular muscle lying in the region of the ciliary annulus, close to the inner surface of the anterior border of the sclera, and is distinguished from the remaining parts of the chorioid by the scantiness of its pigmentation. Its shape in section is almost that of a three-sided prism, so that in cross-section it appears triangular, with the longest side of the triangle close to the inner surface of the sclera. It consists of outer meridional fibers and inner circular fibers, the latter not coursing exactly equatorially, but obliquely or radially. The origin of the main meridional mass of fibers lies on the inner surface of the corneal rima, and from this the fibers pass in a meridional direction backward into the chorioid tissue (tensor chorioideæ). The *orbiculus ciliaris* is that part of the ciliary body which passes over into the chorioid posteriorly, and is a zone about 2 mm. wide, its junction with the chorioid coinciding with the ora serrata of the retina (page 253). Here certain structural peculiarities of the chorioid (the lamina choriocapillaris) cease, a thickening of the coat appears, and gradually the folds of the ciliary corona, so characteristic of the inner surface of the ciliary body, begin. The corona consists of seventy (more rarely seventy-one to seventy-two) radiating, deeply pigmented processes, the *ciliary processes,* which begin even in the region of the orbiculus ciliaris as very low folds and gradually increase in height toward the iris, attaining their greatest height of about 1 mm. immediately along the external border of the iris. Examined with a lens, they are seen to be not smooth, but finely notched and swollen, their free borders projecting into the cavity of the eyeball. Frequently a single ciliary process is formed by the blending of several folds of the orbiculus ciliaris. The

* The border of the chorioidal foramen often appears as a dark ring about the optic disc, when the eye is examined with the ophthalmoscope.

FIG. 733.—The anterior half of an equatorially bisected right eyeball, as seen from behind. The vitreous body has been removed. (Enlarged five times.)

n = Nasal; t = temporal.

FIG. 734.—The posterior half of an equatorially bisected right eyeball, as seen from in front. The vitreous body has been removed. (Enlarged five times.)

t = Temporal; n = nasal.

FIG. 735.—A portion of the preparation depicted in Fig. 733. (Enlarged ten times.)

FIG. 736.—The posterior surface of the iris and of the ciliary body after the removal of the lens. (Enlarged ten times.)

Upon the left the zonular fibers have been removed. * = Folds of the iris.

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free ends of the processes do not reach the lens, but remain at a distance of about 1 mm. from its equator, and in the furrows between the processes is a variable number of folds, which project less strongly, are narrower and shorter, although resembling in appearance the ciliary processes; these are the *ciliary folds*, and both the folds and the processes appear to have a dark color because they are covered by the pigment layer of the retina, the pigment stratum of the ciliary body (page 253). The fibers of the ciliary zonule (page 257) pass through the groove between the processes, and the folds and processes together form the ciliary *corona*.

The Iris.—The iris (Figs. 728 to 732, and 736) has the form of a disc with a circular opening in the middle, this disc being placed perpendicular to the axis of the eye and separated from the cornea by the anterior chamber of the eye. The *anterior surface* is almost plane, being made slightly convex anteriorly only by the anterior surface of the lens, and faces the anterior chamber of the eye, while the *posterior surface* partly rests upon the anterior surface of the lens and partly bounds the posterior chamber. The inner sharp border, surrounding the *pupil*, is almost exactly circular and is known as the *pupillary margin*, and the outer border, passing over into the ciliary body, is the *ciliary margin*. It is connected with the posterior surface of the cornea, and especially with its posterior elastic membrane, by the *pectinate ligament*, a structure only weakly developed in man, and consisting of a number of separate lamellæ, separated by fine (microscopic) spaces, the *spaces of the angle of the iris* (spaces of Fontana); it rounds off the angle between cornea and iris, known as *the angle of the iris* (see below).

The *pupil* is a practically circular aperture situated exactly, or almost so,* in the center of the iris, and differing in size according to its state of contraction.

The anterior and posterior surfaces of the iris are decidedly dissimilar in appearance. On the anterior surface, about 1 mm. from the pupillary border, is a slightly serrate line or ridge, concentric to the pupillary border; it separates the narrow pupillary zone of the iris, the *annulus iridis minor*, from the broad ciliary zone, the *annulus iridis major*. The former shows (only when examined with a lens) fine, shallow indentations, which increase in number toward the pupil, the latter, in light eyes (blue or bluish gray) shows wavy radial stripes, corresponding to blood vessels. The pupillary border of the iris itself, especially when the dilator iridis is relaxed, has a slightly serrate appearance, this serration being an expression of the radial folds of the posterior surface of the iris which extend to the pupillary border, and the serrated border is also dark, since the pigment of the posterior surface extends to the very border.

* To be exact, the center of the pupil is a little nasal to the center of the iris.

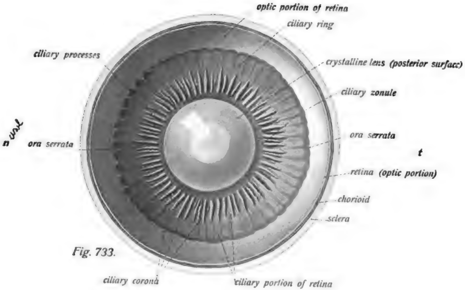

Fig. 733.

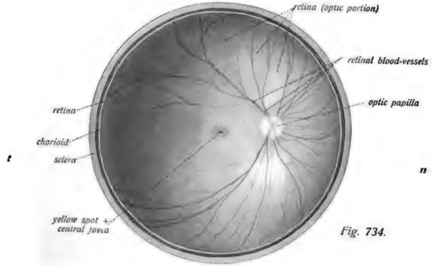

Fig. 734.

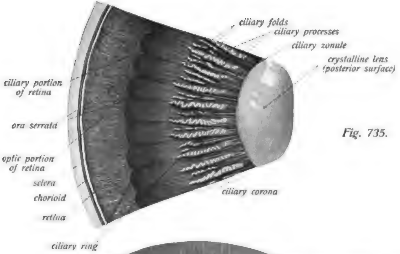

Fig. 735.

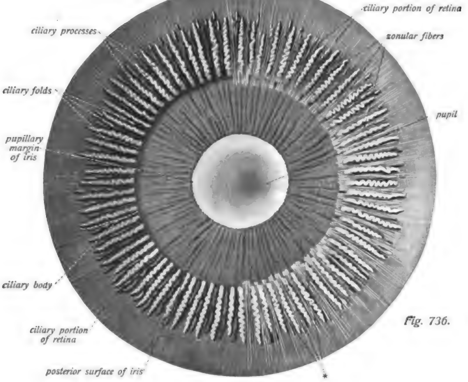

Fig. 736.

The individual color variation of the anterior surface of the iris is due to a greater or less amount of pigmentation. In blue or bluish-gray eyes the iris is poor in pigment and permits the pigment of the pigmented epithelium of the retina, lying on its posterior surface, to shine through; in darker (dark-brown or brown eyes) the stroma of the iris itself is rich in pigment. The anterior surface is covered by the endothelium of the anterior chamber (page 250), and, furthermore, in the ciliary part it usually shows contraction folds, concentric to the pupil, the *folds of the iris.*

The posterior surface of the iris is covered by retinal pigment up to the pupillary border, and possesses very fine, but distinct, radial folds which cannot be seen except through a lens. It lies only loosely upon the anterior surface of the lens, and moves upon it in dilation and contraction of the pupil.

In addition to the anterior endothelium and the posterior epithelium the iris consists of a matrix, the very vascular *stroma*, and of musculature. The latter consists of the *sphincter pupillæ*, which surrounds the pupillary border like a ring, and the *dilator pupillæ*, which lies on the posterior surface and should not be regarded as really belonging to the stroma of the iris, but to the posterior epithelial stratum. The greatest thickness of the iris is about 0.4 mm., and its average width, from the ciliary to the pupillary border, is 3 mm.

THE RETINA.

The *retina* (Figs. 728 to 730, 733 to 738, and 742), as a whole, consists of two layers adhering closely to one another and fused at the pupillary border of the iris. The external layer lies close to the vascular tunic and is entirely absent at the point where the optic nerve pierces the coats of the eye. It is pigmented throughout its entire extent and is known as the *pigmented layer of the retina* and since it covers all the projections of the vascular tunic, such as ciliary processes, etc., it may be divided into the *pigmented stratum of the retina*, the *pigmented layer of the ciliary body* (see above), and the *pigmented layer of the iris* (see below). The internal layer, the true retina, is divided into two sharply separate portions, a posterior thicker main portion, which is the percipient portion, and is known as the *optic portion*, and an anterior nonpercipient portion, the *ciliary portion.** The two parts pass into each other along a slightly serrated line, the *ora serrata*, which lies 3 to 4 mm. in front of the equator of the eyeball, at about the junction of the anterior and middle thirds of its surface. It extends much closer to the ciliary corona on the nasal than it does on the temporal side, or, in other words, the orbiculus ciliaris is perceptibly narrower on the nasal than it is on the temporal side, and furthermore, delicate prong-like processes of the ora serrata frequently occur on the nasal side, while on the temporal side it is merely wavy.

The optic portion of the retina is a very soft, delicate membrane, which is perfectly transparent in the living condition, although it is not quite colorless.† In the cadaver it has a grayish-white appearance and is opaque. It gradually increases in thickness from the ora serrata (0.62 mm.) to the posterior surface of the eye, and reaches its greatest thickness in the neighborhood of the axis of the eye (0.2 mm.). Here it presents a rather indistinctly outlined, yellowish (orange), diffuse coloration, the so-called *yellow spot* (*macula lutea*).‡ In the center of the macula lutea

* Also known as pars cæca retinæ.

† The retina has a diffuse pigmentation, the visual purple, in its outer layers.

‡ It has recently been maintained that the yellow color of the macula lutea is a post-mortem phenomenon, but this supposition has been opposed, and with reason.

FIG. 737.—The background (ophthalmoscopic picture) of a moderately pigmented eye (from Haab-de Schweinitz, *Atlas and Epitome of Ophthalmoscopy and Ophthalmoscopic Diagnosis*).

The retinal vessels show distinct reflex striæ. The optic papilla exhibits a distinct scleral ring, but an obscure chorioidal ring.

FIG. 738.—The background (ophthalmoscopic picture) of a slightly pigmented eye (from Haab-de Schweinitz, *Atlas and Epitome of Ophthalmoscopy and Ophthalmoscopic Diagnosis*).

The chorioidal vessels may be seen through the transparent tissues. The optic papilla exhibits distinct scleral and chorioidal rings.

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is an indentation, the *central fovea*, whose floor extends almost to the pigment layer, so that the latter shines through this portion of the retina much more strongly than it does in other places. To the nasal side of the macula lutea there is an almost circular, sometimes slightly raised, pure white, opaque spot in the optic portion of the retina, which is the point of entrance of the optic nerve and is known as the *papilla of the optic nerve*.* From this point the optic nerve, which has pierced the sclera and chorioid (pages 249 and 251), spreads out in such a way, that its fibers form the superficial layer of the retina. (For details as to the structure of the retina see the Sobotta-Huber *Atlas and Epitome of Histology*.) Since all other layers of the retina are absent at the optic nerve papilla, this region is also known as the blind spot. In the middle of the papilla there is usually an indentation, the so-called physiological excavation, or the *excavation of the papilla of the optic nerve*, and at this point the central vessels of the retina, coursing in the optic nerve (page 261) make their appearance, and from here are distributed in the superficial layers of the retina. The branches of the central artery of the retina (see page 261) are known as arterioles, the branches of the central vein as venules, and of each of these four main branches may be recognized, two temporal and two nasal, which are already formed before the vessels actually reach the papilla, that is to say, while they are yet within the optic nerve trunk. According to their course, they are known as the *superior temporal*, *inferior temporal*, *superior nasal*, and *inferior nasal arterioles* (*venules*) (Fig. 742) of the retina. Beside these four main vessels, usually three smaller ones are present: first, the *superior* and *inferior macular arterioles* (*venules*) passing to the region of the macula, and second, the usually very small *medial arterioles* (*venules*), passing almost horizontally toward the nose. The final branches of the retinal vessels disappear toward the ora serrata, and all veins accompany the arterial branches as single stems.

The *ciliary portion* of the retina, better known as the cæcal portion, is divided into the true ciliary portion, which covers the inner surface of the ciliary body, and that part lying on the posterior surface of the iris, the so-called iris portion, which, at the pupillary border, passes over into the pigment epithelium. The two parts are distinguished from one another by the fact that the ciliary part (in a narrower sense) is unpigmented, while the iris part is pigmented. Since the whole ciliary portion of the retina consists of only a single layer of cubical epithelium, a sudden decrease in the thickness of the retina (to about 0.009 mm.) occurs at the ora serrata, although there has already been a decided thinning of the optic portion (0.02 mm.). In the region of the orbiculus ciliaris the pigment epithelium shows through the ciliary portion of the retina, which is not pigmented in this region, so that this part of the inner surface of the eyeball (especially in the cadaver) seems much darker than the posterior part, which is covered by the

* Since the nerve usually does not project beyond the level of the retina, the term disc would be preferable to papilla.

Fig. 737.

Fig. 738.

optic portion of the retina. At the pupillary border the iris portion of the retina becomes continuous with the outer layer, so that the posterior surface of the iris is covered by two layers of pigmented epithelial cells (pigmented layer of the iris).

In studying the interior of the living eye (opthalmoscopic picture) (Figs. 737 and 738) the posterior surface is seen to be decidedly red and differs in different individuals according to the amount of general pigmentation, being either of a lighter or a deeper red. The red color does not come from the retina, which is transparent, but from the vascular tunic, to whose vascularity it is due, and according as the pigment of the pigmented layer of the retina is sparse or abundant, the color of the choriocapillaris is more or less clearly seen. The pigment of the chorioid itself is often seen distinctly in dark eyes, usually in the form of darker lines or spots which correspond to the intervals between the chorioidal vessels. In contrast to the general deep-red color of the posterior surface is the much lighter, rather pale grayish-red of the papilla of the optic nerve; the nerve fibers, which in this situation are destitute of medullary sheaths,* are, therefore, transparent, but the chorioid, being absent, does not serve as a substratum here, the whitish sclera (lamina cribrosa) and the medullated fibers of the optic nerve behind the lamina cribrosa forming the background, which is, therefore, white, especially the part behind the middle of the papilla, where there is a deep depression. The papilla is often surrounded by a narrow, dark ring, which corresponds to the borders of the chorioidal opening and is known as chorioidal ring. From the papilla the distribution of the retinal vessel in the retina may be seen, the arteries being narrower than the veins and having a broader reflection band in the middle. On the temporal side of the papilla the macula lutea and fovea centralis may be seen, the surface being usually more pigmented in their neighborhood.

THE CONTENTS OF THE EYEBALL.

The contents of the eyeball, enclosed by the three tunics, are transparent, partly liquid, partly solid media, the most important of which is the *crystalline lens*, lying in front of the equator of the eyeball, behind the iris. Between the posterior surface of the cornea and the anterior surface of the lens is a space filled by a watery liquid, the *aqueous humor*; this is the chamber of the eye and is divided by the iris, which projects into it, into an *anterior* and *posterior chamber*. The space between the posterior surface of the lens and the retina is occupied by a peculiar tissue, the *vitreous body*.

The Anterior Chamber of the Eye.—The anterior chamber of the eye (Figs. 729 and 730) has the shape of a segment of a sphere. It lies between the posterior surface of the cornea and the anterior surface of the iris or, in the region of the pupil, the anterior surface of the lens. The acute angle of this chamber, which is formed by the pectinate ligament between iris and cornea, is known as the *angle of the iris*. Since the iris lies only loosely upon the anterior surface of the lens, the anterior chamber communicates directly with the posterior one. Over its whole extent it is covered by a very regularly arranged pavement-like layer of connective-tissue cells, the *endothelium of the anterior chamber*.

The Posterior Chamber of the Eye.—The posterior chamber of the eye (Figs. 729 and 730) is much smaller than the anterior. It is a ring-shaped space, bounded anteriorly by the posterior surface of the iris, posteriorly by the anterior surface of the lens and the zonula ciliaris, and externally by the points of the ciliary processes and their connections with the zonula ciliaris. The transverse section of the space is triangular, the smallest angle facing the axis of the eye.

The Crystalline Lens.—The *lens* (Figs. 729, 730, 735, 736, and 739 to 741) is a transparent biconvex body, which lies between the posterior surface of the iris and the anterior surface of the vitreous body, closing the pupil. It possesses a slightly curved anterior and a more

* Sometimes the fibers of the optic nerve remain medullated even after their passage through the lamina cribrosa. Such fibers then appear close to the papilla as almost pure white bundles in the red fundus of the eye.

FIG. 739.—The lens as seen from in front. (Enlarged six times.)
* = Lens star.
FIG. 740.—The lens as seen from the equator. (Enlarged six times.)
FIG. 741.—The lens equatorially bisected and the capsule partly stripped off. (Enlarged six times.)

strongly curved posterior surface, which pass into each other at the *equator of the lens*, forming a convex border. The center of the anterior surface is known as the *anterior pole*, that of the posterior surface as the *posterior pole*, and the line connecting the two is the *axis of the lens*. Its length depends upon the condition of accommodation of the eye and fluctuates between 3.7 and 4.4 mm.*

The true substance of the lens is completely surrounded by a homogeneous, slightly adherent *capsule*, to which, in the region of the equator, the fibers of the ciliary zonule become attached, and, on the posterior surface of its thicker anterior part, there is a simple layer of cells, the epithelium of the lens. The substance of the lens, enclosed by the capsule, consists of a rather firm *nucleus* and a softer *cortical substance*, which merge into one another, however, and are both formed by *lens fibers*. These pass from the anterior to the posterior surface and correspond to the curvature of the surface in such a way as to give rise to radiating seams on both surfaces, each of which consists of three main rays, *radii of the lens*, which form a Y-shaped figure,† whose branches often show divisions and forkings, so that irregular multirayed stars having six and nine rays may occur. The limbs of the Y have a different position on the anterior and posterior surfaces, being inverted anteriorly and erect posteriorly. The anterior surface of the lens, as already indicated, is in relation with the pupil and the anterior chamber of the eye, and, more peripherally, with the posterior surface of the iris. The fibers of the zonula ciliaris are inserted in the region of the equator, which is in direct relation with the ciliary zonule, but is about 1 mm. distant from the points of the ciliary processes. The posterior surface of the lens lies in a depression of the vitreous body, the *hyaloid fossa*. The lens is, developmentally, a purely epithelial structure, and possesses neither nerves nor blood-vessels, sharing this peculiarity with only a few tissues of the human body (enamel of the teeth).

The Vitreous Body and the Zonula Ciliaris.—According to their development the vitreous body and the zonule are closely related, the latter being merely a special formation of the vitreous body. Together they completely fill the principal cavity of the eyeball, lying behind the lens and the ciliary body.

The *vitreous body* (Fig. 730) is a sphere whose anterior surface is slightly flattened and presents a depression, the *hyaloid fossa*, for the reception of the posterior surface of the lens. It consists of a watery liquid, the *vitreous humor*, distributed in the meshes of a delicate network, the *vitreous stroma*, this latter thickening over the whole surface of the vitreous body to form a firm, *hyaloid membrane*, which lies upon the inner surface of the retina and is loosely connected with it.

The distribution of the vitreous humor in the stroma gives a gelatinous consistency to the

* In focussing the lens for distance the length of the axis is 3.7 mm. and the radius of the anterior surface 6 mm.; in focussing for a near object the lens thickens, the length of the axis is 4.4 mm., the radius of the anterior surface 5.2 mm., and of the posterior surface 5 mm. Thus in the latter focus it is the curvature of the anterior surface which varies most.

† This figure becomes very evident when the lens is subjected to a certain amount of maceration and when the cement substance between the fibers begins to dissolve. Then the rays become fissures.

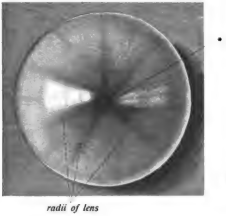

Fig. 739.

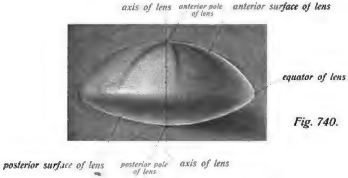

Fig. 740.

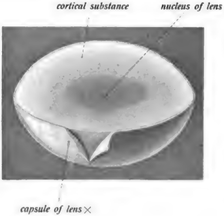

Fig. 741.

entire body. While in its fully developed condition the vitreous body is devoid of vascular supply, it does contain blood-vessels in the embryo, especially a small artery passing from the region of the papilla of the optic nerve to the posterior surface of the lens, the *hyaloid artery*, which is a prolongation of the central artery of the retina (see page 261). It lies in the *hyaloid canal*, which, even after the obliteration of the artery, is still recognizable.

The ciliary zonule (zonule of Zinn) (Figs. 730, 733, 735, and 736) is the ring-shaped, delicate and transparent suspensory apparatus of the lens. It is closely connected with the hyaloid membrane and consists of meridional *zonular fibers*, which are very fine, but strong, and have their origin from the whole width of the orbiculus ciliaris, being closely connected with the cells of the ciliary part of the retina. At the posterior ends of the ciliary processes the fibers of the zonula collect into close bundles which course toward the lens through the furrows between the ciliary processes, being strengthened by a few fibers coming from the lateral border of the ciliary processes and folds, and after decussating with one another are inserted into the capsule of the lens in the region of the equator. The attachment of the zonula fibers is not limited to the actual equator of the lens, but extends also upon the neighboring portions of the posterior and especially the anterior surface, the fibers, as they diverge toward their insertion, leaving relatively wide spaces between them, called *zonular spaces*, which contain aqueous humor, since they are in communication with the posterior chamber.

THE BLOOD-VESSELS AND NERVES OF THE EYEBALL.

In addition to the optic nerve and the central retinal vessel enclosed within it (page 261), a number of vessels and nerves pass to the eyeball and ramify in its coats and especially in the vascular coat. Since the retina (optic portion) has its own vessels entering with the optic nerve, and the cornea is entirely devoid of vessels, while the sclera is but poorly provided with them, the distribution of the blood-vessels of the eyeball is almost limited to the tunica vasculosa, whence its name.

THE BLOOD-VESSELS OF THE EYEBALL.

The nutritive arteries of the eyeball are known as the *ciliary arteries* (Figs. 743 and 744) and arise from the ophthalmic artery (page 31), partly directly as the *posterior ciliary arteries*, partly indirectly from its muscular branches as the *anterior ciliary arteries*. The posterior ciliary arteries are much the stronger and, lying close and almost parallel to the optic nerve, they pass through the capsule of Tenon (see page 265) and divide into (1) branches, which after a short course pierce the sclera in the posterior part of the eyeball and at once ramify in the chorioid (the *short posterior ciliary arteries*, fifteen and twenty in number), and (2) into two *long posterior ciliary arteries*, which also pierce the sclera in the vicinity of the entrance of the optic nerve, but then pass to the ciliary body along the horizontal meridian of the bulb, one on the nasal and the other on the temporal side, in the outer layer of the chorioid.

The short posterior ciliary arteries are the arteries for the chorioid proper, while the long ciliary arteries, together with the anterior ciliaries, supply the ciliary body and the iris. Their capillary distribution also differs in that the short, posterior ciliary arteries form the choriocapillaris (page 251), which is in close contact with the retina and is largely responsible for its nutrition, but is absent in the anterior part of the bulb.

The *anterior ciliary arteries* are branches of the muscular rami to the recti muscles of the eyeball (page 264), and pierce the sclera near the insertion of their tendons, that is to say, near the sclerocorneal junction and, with the long posterior ciliary arteries, supply the iris and ciliary body in such a way that, in the first place, by anastomoses with the branches of the long posterior ciliary arteries at the base of the iris they form an arterial ring known as the *greater arterial circle of the iris*, and secondly, near the pupillary border of the iris they form a second, smaller vascular ring, which usually is incomplete and is termed the *lesser arterial circle of the iris*. This arises by transverse anastomoses of vessels arising from the major circle and passing radially through

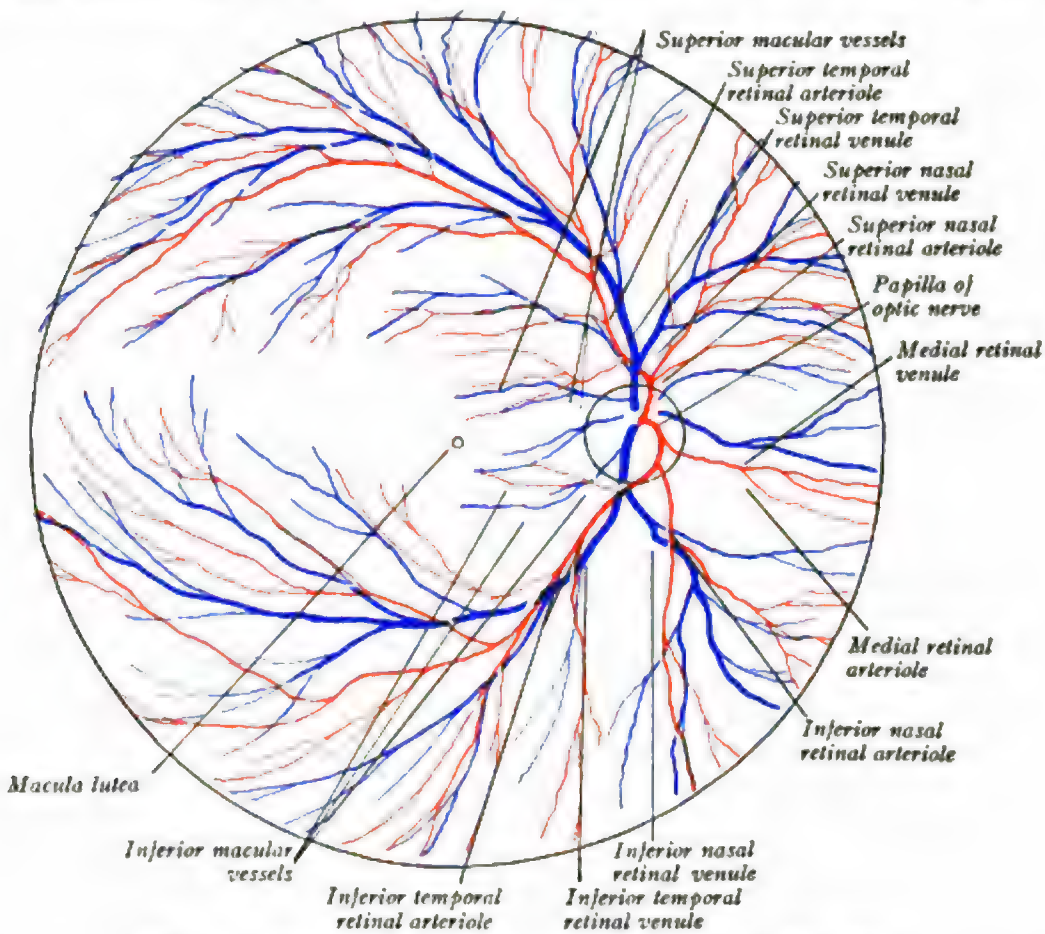

FIG. 742.—The plan of the blood-vessels of the retina of the right eye.

the iris, and from it branches pass to the ciliary muscle, which is also supplied by direct branches of the anterior ciliary arteries, and to the ciliary processes. The region of the orbiculus ciliaris is completely devoid of capillaries, while in the region of the ciliary body a wide-meshed network is formed in the ciliary muscle and a narrower one in the ciliary processes.

The veins of the tunica vasculosa are four to six rather large stems, formed in the region of the equator of the eyeball by the union of numerous small, radiating branches which come from the posterior surface of the eye, as well as from the ciliary body; these stems are the *vorticose veins*, and pierce the sclera obliquely, a little behind the equator, in order to empty into the ophthal-

mic vein (superior or inferior, see page 87). In addition there are also *anterior* and *posterior ciliary veins*, but these are much smaller stems. The anterior ones form the scleral venous sinus (page 249).

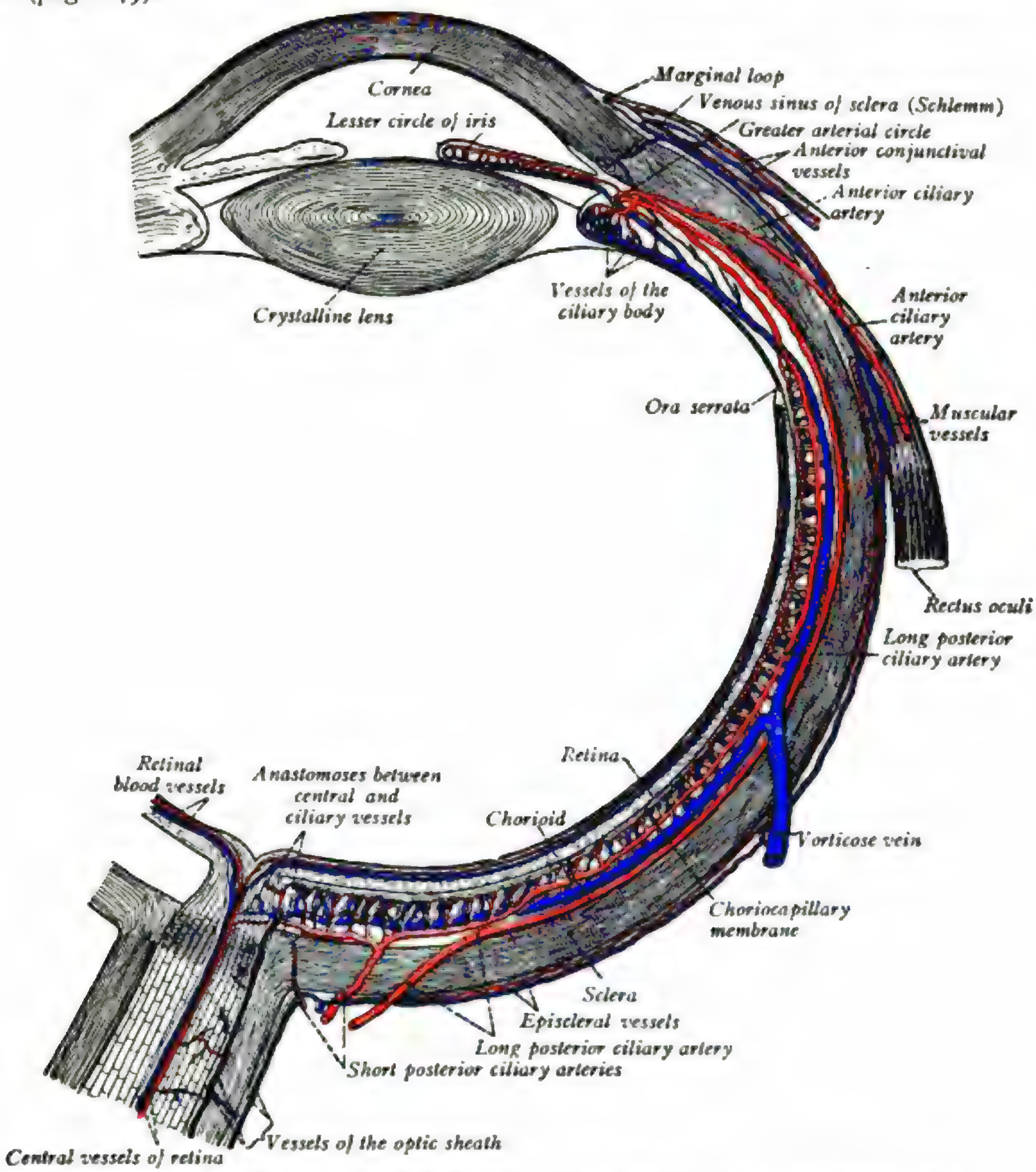

FIG. 743.—The blood-vessels of the eyeball diagrammatically represented. (After Th. Leber).

There are no special lymphatics in the eye, so far as is known. In their place there are extensive lymph spaces, in which must be included the anterior and posterior chamber of the eye and the *zonular spaces;* the *perichorioideal space* (page 251) is also a lymph space, and perhaps, too, the *hyaloid canal.*

THE NERVES OF THE EYEBALL.

The nerves passing to the eye are, in addition to the optic (see page 261), the *long* and *short ciliary nerves* (see pages 197 and 198). They are partly motor, partly sensory, and partly vaso-motor, and arise from the oculomotor, trigeminal (the nasociliary branch of the ophthalmic nerve) and sympathetic nerves. They penetrate the sclera with the posterior ciliary arteries in a circle

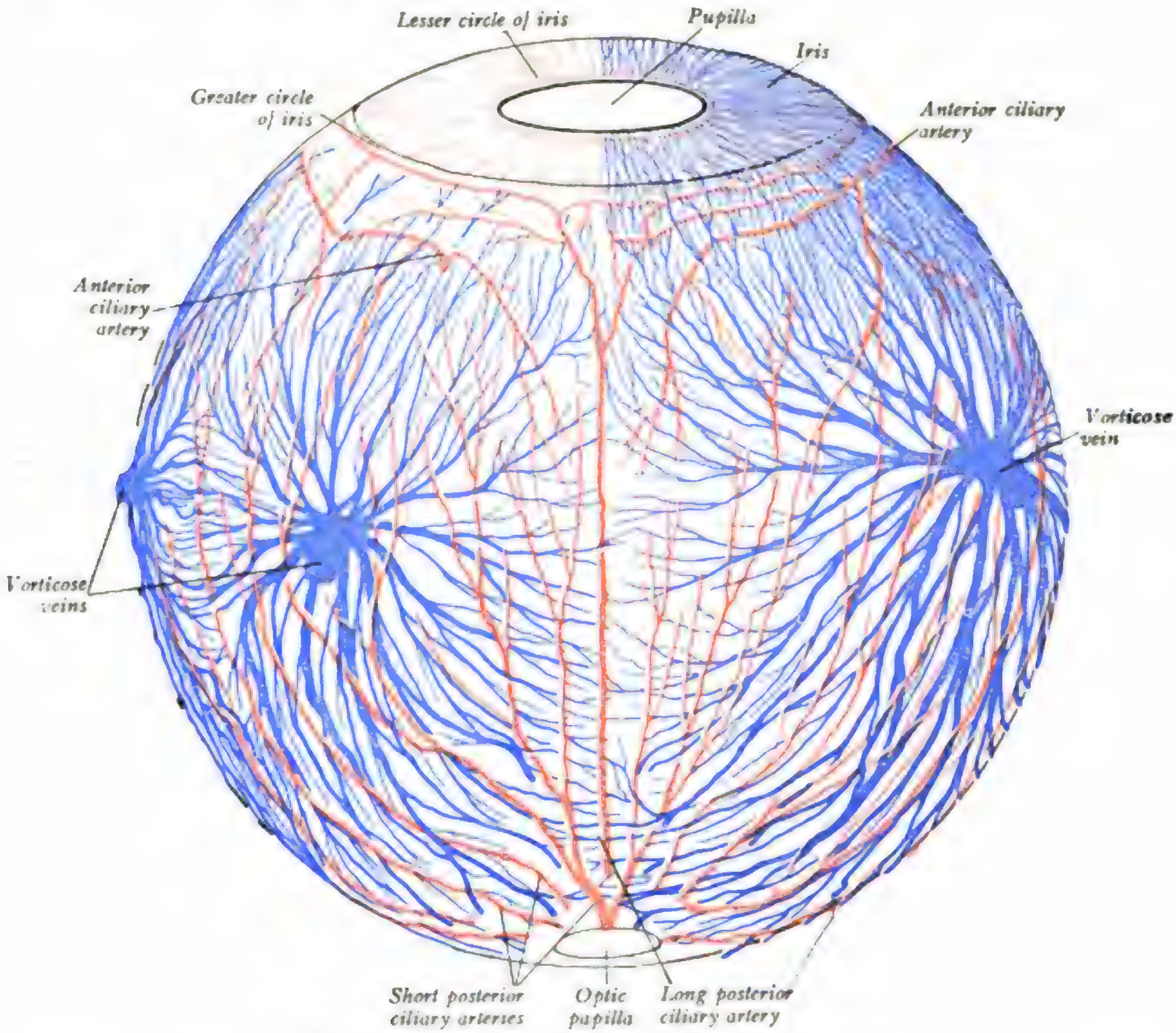

FIG. 744.—The blood-vessels of the eye-ball (diagrammatic).

around the optic nerve (Fig. 731), course with the long posterior ciliary arteries on the external surface of the chorioid, making numerous anastomoses with one another, and pass to the ciliary body, where they form on the ciliary muscle the *ciliary ganglionic plexus*, rich in ganglion cells (sympathetic). From this, fibers pass to the ciliary muscle, the iris, and the cornea. The motor

fibers for the sphincter pupillæ arise from the oculomotor, while those of the dilator are from the sympathetic nerve.

The Optic Nerve.—The optic nerve (Figs. 729, 730, and 745 to 747) arises from the optic chiasma (see page 154); in all its relations it is, like the retina, a projecting part of the brain, as can be seen from its development (see below). Among other things, the meninges, the dura, as well as the pia, are continued upon it and accompany it to the eyeball.

While the nerve is slightly flattened in its short course within the cranium, from the optic foramen to its entrance into the eyeball it has an almost perfect cylindrical shape, its diameter being about 4 mm. In passing through the optic foramen it courses above and medial to the ophthalmic artery (see page 263), and is surrounded by the origins of the recti muscles of the eyeball and their tendinous annulus (see page 31). Then, imbedded in the fatty tissue of the

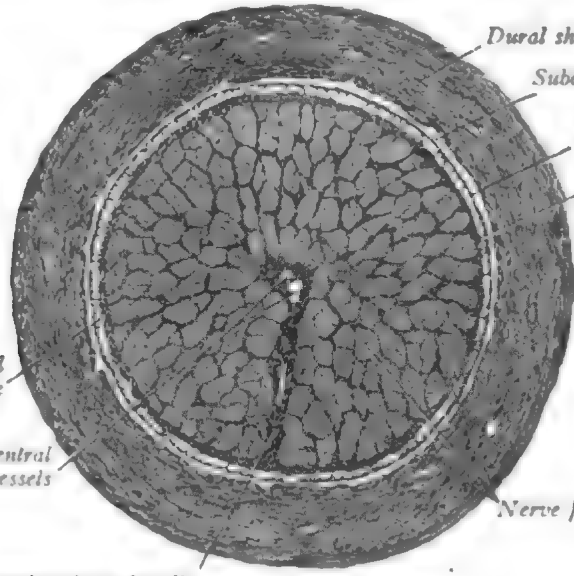

Fig. 745.—A cross-section of the optic nerve.

orbit, it passes in the axis of the muscle pyramid to the medial (nasal) portion of the posterior part of the eyeball, its course in the orbital cavity not being quite straight, but describing a slight S-shaped curve in the horizontal plane, first bending laterally, then back again into the axis of the muscle cone, and finally making a very short lateral bend just before entering the eyeball. Nor does it pass from the optic foramen to the eyeball in the horizontal plane, but is inclined somewhat upward, since its point of entrance into the eyeball is on a slightly higher level than the optic foramen. At a distance of 10 to 12 mm. from the eyeball* the central vessels of the retina enter the optic nerve and pass in the center of the nerve trunk, surrounded by connective tissue, to the papilla, where they form the blood-vessels of the retina (page 254). The entrance of the vessels is in the lower and lateral part of the nerve trunk. Then the nerve passes through the relatively wide opening in the posterior portion of the capsule of Tenon (see page 266), and, on entering the sclerotic lamina cribrosa (page 249), its fibers lose their medullary sheaths, so

* The length of the portion of the optic nerve lying in the orbit is about 23.5 mm.

FIG. 746.—A horizontal section of both orbits.

The section has been carried somewhat obliquely posteriorly, in order to show the entire length of both optic nerves.

FIG. 747.—The two eyeballs, with their optic nerves, from a child.

The orbits have been freely opened from above and their entire contents removed with the exception of the eyeballs and the optic nerves.

FIG. 748.—The ocular muscles seen from the outer side.

The outer wall of the orbit and the other orbital contents, including the fascia and the eye-lids, have been removed. The greater portion of the levator palpebræ superioris has been retained.

FIG. 749.—The ocular muscles seen from the outer side.

Dissection as in Fig. 748. In addition, the rectus lateralis and the optic nerve have been divided and the eye-ball has been rotated so that its posterior pole, with the stump of the optic nerve, is directed outward. The greater portion of the levator palpebræ superioris has been removed.

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that the nerve becomes decidedly thinner, its terminal portion, ending in the papilla of the optic nerve, having a somewhat tapering appearance. The nerve then pierces the chorioid and passes directly over into the retina (see page 253).

The coats of the optic nerve are, as already stated, the direct continuations of the meninges and are called the *sheaths of the optic nerve.* Within the cranium the nerve is surrounded only by the pia mater, the so-called *pial sheath*, but at the optic foramen the encephalic dura mater (see page 188) is prolonged as the *dural sheath* over the whole length of the optic nerve and becomes attached to the sclera, while between the pial and dural sheaths the encephalic arachnoid extends along the nerve, forming the *arachnoideal sheath.* The *intervaginal spaces* lying between the nerve sheaths correspond to the spaces between the meninges and are in direct communication with them, and, in addition, a lymph space, the *supravaginal space*, surrounds both the optic nerve and its sheaths. The fibers of the optic nerve undergo an incomplete decussation in the optic chiasma (see page 154), the fibers arising from the temporal side of the retina, remaining uncrossed. The bundle of fibers which comes from the region between the papilla of the nerve and the macula lutea has a definite location in the nerve; it is known as *papillomacular bundle* and lies on the temporal side of the nerve near the eyeball, but in the center of the nerve in its extra-orbital portion.

THE DEVELOPMENT OF THE EYEBALL.

As regards the development of the eyeball, its first indication is the so-called primary *ophthalmic vesicle.* This is a vesicular projection of the (primary) anterior brain vesicle, and in the further course of development it becomes stalked and approaches to the outer surface of the head. From the stalk, which connects the vesicle with the cerebrum, the optic nerve develops; from the vesicle itself, the internal coat of the eye. In the further development, the previously almost spherical vesicle becomes invaginated on its outer surface, so that there is formed a double-walled cup, the so-called secondary ophthalmic vesicle or the *ophthalmic calyculus.* The inner lamina of the cup is separated from the outer one only by a cleft, and the former thickens during further development to form the optic portion of the retina, while its anterior part forms the ciliary portion. From the outer lamina the pigment epithelium is formed. Both layers pass into one another at the opening of the calyx as they do all through life at the pupillar border of the iris. The ophthalmic calyculus has a slit on its inferior surface, the fœtal ocular fissure, through which the neighboring blood-vessels enter the cup and traverse the vitreous body, which develops later.

Of the other parts of the eyeball the lens also is developed from the outer germinal layer as a thickening of the embryonic epidermis. It becomes constricted off from the parent layer and comes to lie in the opening of the calyculus, where its cells are transformed into lens fibers and produce (as a cuticular formation) the homogeneous capsule. The first traces of the vitreous body and the ciliary zonule are formed from the retina, the fibers of both being processes from the retinal cells, but later, blood-vessels growing through the fœtal ocular fissure into the interior of the eye, form the

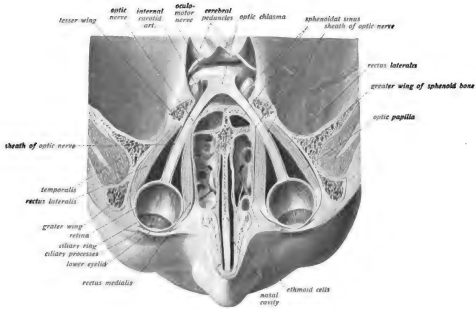

Fig. 746.

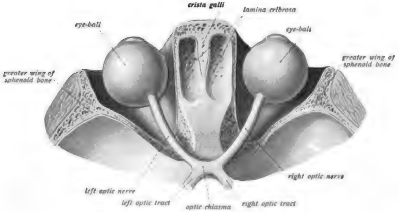

Fig. 747.

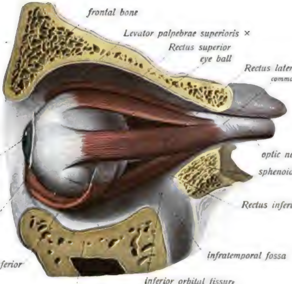

Fig. 748.

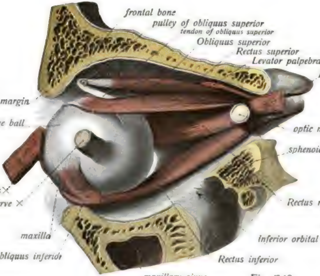

Fig. 749.

hyaloid artery and the *vascular capsule of the lens*, which, as the *pupillary membrane*, also covers the anterior surface of the lens, but which later, after the closure of the ocular fissure, disappears entirely. The vascular and fibrous tunics are formed from the embryonic mesenchyme. The cornea is at first only a transformed portion of the fibrous tunic, around which the eyelids grow at a much later stage.

ACCESSORY ORGANS OF THE EYE.

THE MOTOR APPARATUS OF THE EYEBALL.

THE MUSCLES OF THE EYE.

The movements of the eyeball are performed by six muscles, four of which are straight, the *recti muscles*, and two oblique, the *oblique muscles* (Figs. 546, 547, 682, 683, and 748 to 761). The four recti have many features in common; they are long, flat muscles, narrow posteriorly and broad anteriorly, having a straight course, and they are inserted by short, narrow, flat tendons, about 1 cm. wide, at almost regular intervals from one another, into the eyeball, anterior to the equator and posterior to the sclerocorneal junction. The two oblique muscles are very different

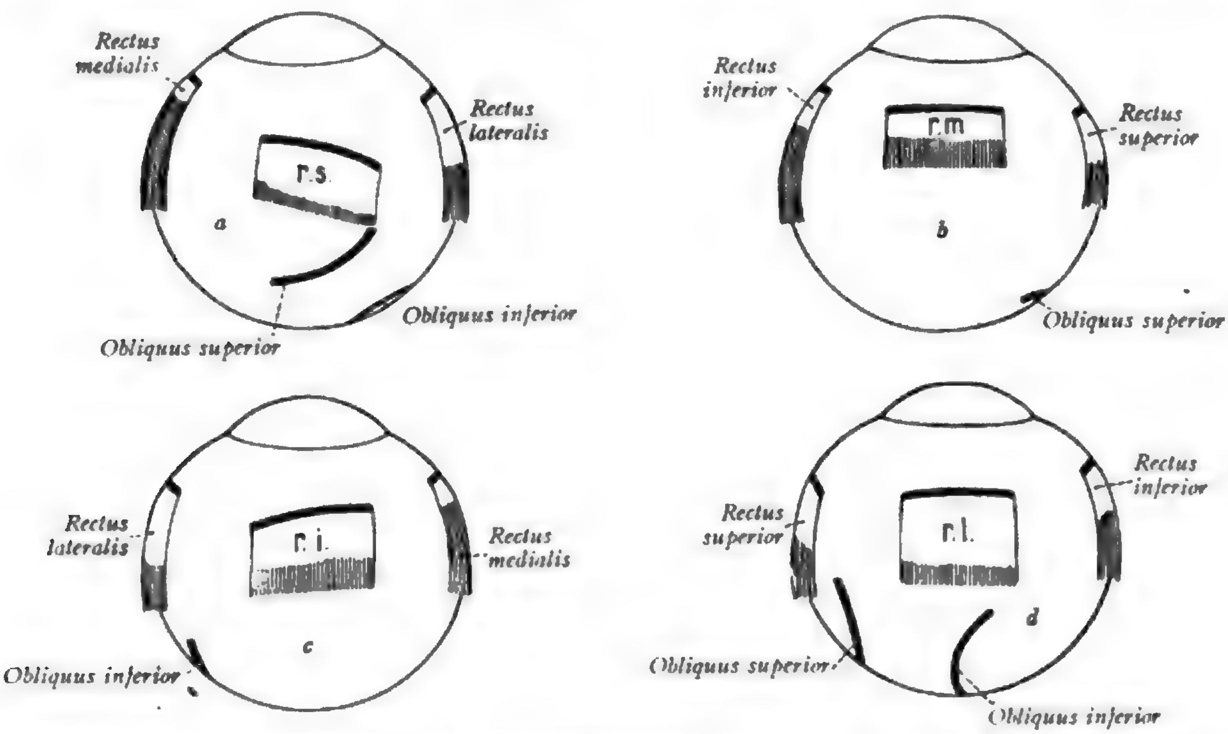

FIG. 750.—The plan of the insertions of the eight ocular muscles as seen: *a*, From above; *b*, from the inner side; *c*, from below; *d*, from the outer side.

from one another, their only common features being their oblique course and their insertion behind the equator.

Of the six muscles, five have a common origin at the optic foramen, where they arise by short tendons from a ring, the *common tendinous annulus* (annulus of Zinn), which surrounds the optic nerve. With these five is associated, at its origin, the levator palpebræ superioris (see page 266).

The *superior rectus* (Figs. 748 to 756, and 758 to 762) is the weakest and thinnest of all the eye muscles; it passes with the levator palpebræ superioris, largely covered by it and partly in close contact with it, over the surface of the optic nerve and the upper quadrant of the bulb, to its insertion just in front of the equator. The lateral part of its tendon is separated from the corneal border by a greater distance than the medial part, which reaches almost to the cornea.

The function of this muscle is to move the anterior part of the eyeball, that is to say, the cornea and pupil, up and at the same time a little temporalwards. It is innervated by the superior branch of the oculomotor nerve.

The *medial rectus* (Figs. 749 to 751, 753 to 760, and 762) is the strongest of all the eye muscles, but as regards its length, it is shorter than the superior rectus and has a very short tendon, the shortest of all; its tendon is inserted nearest to the border of the cornea, along a line almost exactly parallel with the equator, the muscle lying almost in a sagittal plane.

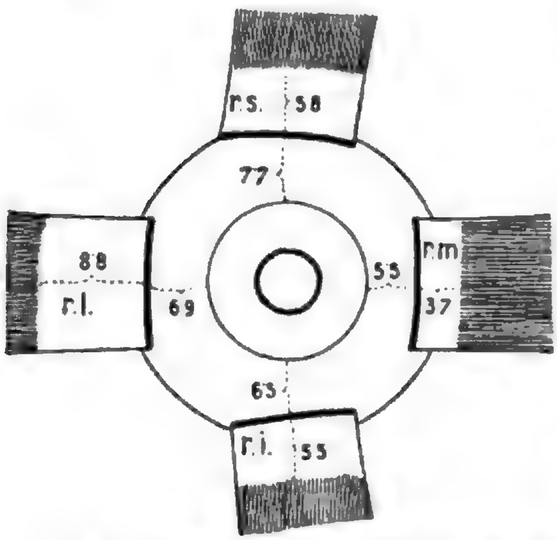

Fig. 751.—The plan of the insertions of the recti into the right eyeball. The measurements of the tendons and the distances from the corneal margin have been inserted according to Merkel-Kallius (Graefe-Saemisch's *Handbuch*). The muscles have been shaded. *ri* – Rectus inferior, *rl* – rectus lateralis, *rm* – rectus medialis, *rs* – rectus superior.

It turns the eyeball medially and is innervated by the inferior branch of the oculomotor.

The *lateral rectus* (Figs. 748 to 760, and 762) does not lie exactly sagittally, as does the medial, but deviates a little from the sagittal plane. Although its insertion is further away from the periphery of the cornea than that of the medial, it must necessarily be longer than it (because the orbital axes converge posteriorly); however, its greater length is due entirely to the length of the slightly narrower tendon, the muscle substance itself being even a little shorter. The insertion of the tendon is in a line parallel with the equator and is a little further from the border of the cornea than that of the medial. Like the preceding muscles, the lateral rectus arises mainly from the common tendinous annulus, but it also has a smaller tendinous origin (*lacertus of the lateral rectus*) from the border of the superior orbital fissure (spine for the lateral rectus muscle, see Vol. I., page 50).

The muscle turns the eye laterally and is innervated by the abducens nerve.

The *inferior rectus* (Figs. 748 to 755, and 758 to 761) lies on the inferior surface of the eyeball, not exactly opposite to the superior rectus, but just as the latter deviates temporally, so does the inferior deviates nasally. The same holds true for the moderately long, rather narrow tendon, whose insertion is oblique, like that of the superior rectus, only in the opposite direction (the lateral portion of the tendon being more posteriorly), and approaches a little nearer the border of the cornea. The muscle is the shortest of all the recti; nevertheless it is stronger than the superior rectus.

The muscle turns the anterior half of the eyeball downward and slightly nasally, and is innervated by the inferior branch of the oculomotor.

The distance of the (middle point of the) recti tendons from the border of the cornea is, on the average, 7.7 mm. for the superior, 5.5 mm. for the medial, 6.9 mm. for the lateral, and 6.5 mm. for the inferior rectus.*

The *superior oblique* (Figs. 749 to 756, 758 to 760, 762, and 763) arises, together with the recti, from the optic foramen (medial border) and from the dural sheath of the optic nerve, and courses forward as a slightly flattened muscle in the upper half of the nasal side of the orbit, and in the interval between the superior and medial rectus, lying close to the periorbita and separated from the eyeball by the adipose tissue of the orbit. The muscle, therefore, is not directed at first toward the eyeball, but behind the trochlear depression or spine of the frontal bone (Vol. I., page 61) it passes over into a cylindrical tendon, which winds through a fibrous or fibrocartilaginous pulley, the *trochlea of the superior oblique*, attached to the frontal bone in this region, from which it is separated by a small mucous bursa, the *trochlear bursa*. From the trochlea the tendon passes obliquely backward and laterally, gradually broadening and thinning as it approaches the bulb; it crosses the superior rectus (passing below it), and, greatly widened, is inserted behind the equator of the bulb, a good centimeter behind the superior rectus, along an oblique line, which lies largely on the temporal side, almost parallel to the axis of the optic nerve.

The pull of the superior oblique is quite different from the course of the muscle, corresponding more to the course of its tendon. It turns the posterior half of the eye upward and nasally (the pupil downward and laterally). It is innervated by the trochlear nerve.

The *inferior oblique* (Figs. 745 to 755, 758 to 763, and 765) is the only one of the six muscles which arises from the anterior part of the orbital cavity, from the superior maxilla, in the posterior region of the infra-orbital margin below the fossa for the lachrymal sac; it is narrow and has a short tendon of origin. It courses obliquely below the lower half of the eyeball, broadening out a little as it goes, crosses the inferior rectus, lying between it and the lateral rectus, and passes to the temporal side of the posterior hemisphere of the eyeball, where it is inserted opposite to the tendon of the superior rectus, but with a narrower and much shorter tendon, along an oblique line, which makes an acute angle with the axis of the eye. It is by far the shortest of all the eye muscles; its tendon is usually rather short.

The muscle moves the posterior hemisphere of the eyeball downward and medially and at the same time a little forward (the pupil upward and laterally), and with the superior oblique it turns the bulb principally about a sagittal axis. It is supplied by the inferior branch of the oculomotor.

The eye muscles are enclosed by muscle fasciæ for the greatest portion of their length, those associated with the recti and the superior oblique becoming much thinner posteriorly, while the stronger anterior portions are a direct continuation of the capsule of Tenon (see below). Only the superior oblique has an evenly thick sheath throughout its length. Processes pass out from the muscle fasciæ, especially from that of the levator palpebræ superioris (see below), and attach themselves to the bony wall of the anterior part of the orbital cavity and to the trochlea. On the attachment of the fascial slips to the lateral part of the orbital opening is the superior lachrymal gland.

* The statistics given by different observers vary considerably, and undoubtedly there are considerable individual variations.

FIG. 752.—The ocular muscles as seen from in front and from the outer side.

The skin, eyelids, and fascia have been removed. In addition to the eyeball and the muscles only the upper lachrymal gland and a portion of the orbital fat have been retained.

FIG. 753.—The eyeball with the stumps of the ocular muscles as seen from in front.

FIG. 754.—The eyeball with the stumps of the ocular muscles as seen from below and from behind.

FIG. 755.—The eyeball with the stumps of the ocular muscles as seen from above and from behind.

Figs. 752 to 755 are about one-third larger than the natural size.

FIG. 756.—The muscles of the orbit seen from above.

The superficial layer is shown upon the left side, only the roof of the orbit and the peri-orbital fascia having been removed. The deep layer is shown upon the right side; the greater portion of the levator palpebræ superioris has been removed, together with the orbital fat.

FIG. 757.—A horizontal section of both orbits.

* = iris.

FIG. 758.—A frontal section of the right orbit in the region of the posterior third of the eyeball. Seen from in front and enlarged about one-third.

FIG. 759.—A frontal section of the right orbit behind the eyeball. Seen from in front and enlarged about one-third.

FIG. 760.—The origins of the muscles of the right orbit at the optic foramen. (Enlarged about one-third.)

The orbital cavity has been sawn in the frontal plane and the posterior section is viewed from in front. The optic nerve is divided close to the optic foramen; the stumps of the muscles situated about the optic nerve have been retained in different lengths. Only the lower branch of the oculomotor nerve has been left *in situ*.

FIG. 761.—A sagittal section of the orbit with the eyeball, somewhat diagrammatic in reference to Tenon's capsule (according to H. Virchow). (Enlarged about one-third.)

* = Site of the firm connection of the capsule with the muscle.

The Capsule of Tenon.—The capsule of Tenon or *fascia bulbi* (Fig. 758, 761, and 762) is a hollow, spherical structure composed of connective tissue, in which the posterior hemisphere of the bulb is located and moves, and by which the eyeball is separated from the adipose body of the orbit. The anterior thickened end of the fascia ends at the conjunctival fornix. The capsule is penetrated (1) by the optic nerve, and (2) by the tendons of the six eye muscles. The optic nerve, together with the nerves and vessels which accompany it (the ciliary arteries and nerves), perforates the posterior thin part of the capsule through an irregularly round hole; * the muscle tendons † pierce the capsule through slit-like openings which have a very oblique direction. From the perforating tendons the fascia bulbi extends backward as a strong fascia upon the adjacent parts of the muscles and becomes continuous with the fascia of the muscle a short distance behind the slit in the capsule.

The capsule of Tenon does not rest directly on the eyeball, but is separated from it, throughout its whole extent, by a narrow space filled with areolar connective-tissue and known as Tenon's space or the *interfascial space*. Anteriorly, this space extends to the conjunctiva of the bulb, but whether it goes over into the supravaginal space (see above) posteriorly, has not been determined.

The Remaining Musculature and the Fascia of the Orbit.—Beside the six muscles moving the eyeball, there is still another voluntary muscle in the orbit, the *levator palpebræ superioris*.

* According to another view the posterior end of the capsule, much diminished in thickness, becomes directly continuous with the optic nerve sheath.

† The slits for the recti are equatorial, and because of their oblique penetration of the capsule, allow only one sharp (inner) lip to be recognized; the slits for the two obliques are meridional.

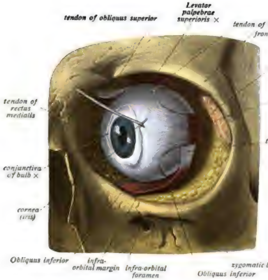

Fig. 752.

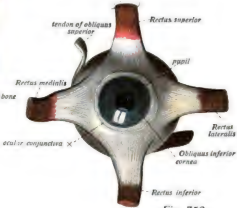

Fig. 753.

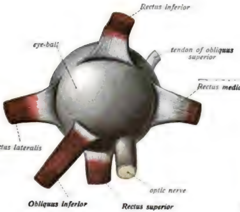

Fig. 754.

Fig. 755.

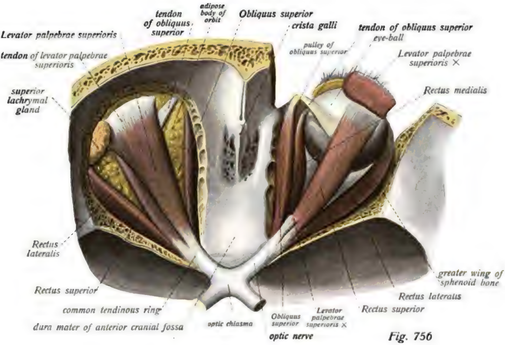

Fig. 756

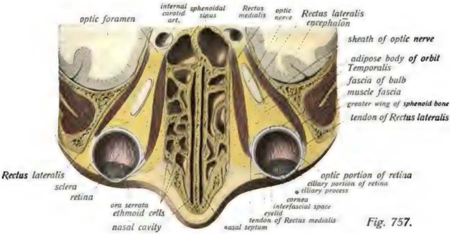

Fig. 757.

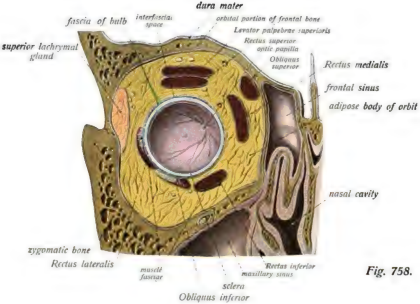

Fig. 758.

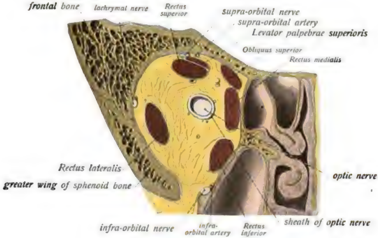

Fig. 759.

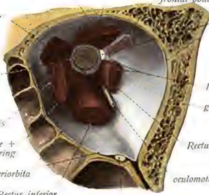

Fig. 760.

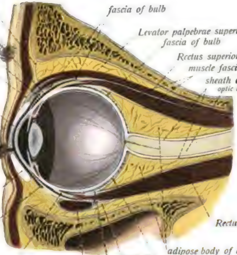

Fig. 761.

It is long, narrow behind and wide in front, and almost completely covers the superior rectus upon which it lies in the posterior part of the orbit, only the lateral border of this muscle remaining uncovered. It arises, together with the superior rectus, by means of a short, narrow tendon, from the common tendinous annulus, and throughout the greatest portion of its length consists of striated muscle fibers. Its tendon, however, contains some smooth muscle fibers, and before its insertion divides in such a way that the posterior part is inserted into the superior border of the tarsus of the upper lid (page 271), while the anterior part is inserted along the whole anterior surface of the tarsus and between it and the palpebral muscle (see page 272).

The muscle raises the upper lid and is supplied by the superior branch of the oculomotor nerve.

Smooth muscle fibers which occur in the periosteum of the orbit form what is called the *orbital muscle*. These fibers occur in variable amounts at different parts of the orbit, and form a strong layer of muscle, which serves to close the orbital fissures (superior and inferior).

The *periorbita* (Figs. 748, 749, and 758 to 760) is the periosteal layer of the orbit, which is continuous with the periosteal layer of the encephalic dura mater at the optic foramen and superior orbital fissure, and with the periosteum of the bones of the face at the inferior orbital fissure. The superior orbital fissure is closed by a thickening of the periorbita, except for the opening traversed by the vessels and nerves.

The *orbital septum* is a fascia-like structure fastened to the aperture of the orbit and pierced in the middle like a diaphragm. It covers the posterior surface of the eyelids and separates them from the true contents of the orbit. This septum is largely formed by the posterior fascia of the orbicularis oculi muscle (see Vol. I., page 179), and, since it extends into the base of the lids, it really belongs to them. The nerves and vessels emerging from the orbital aperture (frontal, supra-orbital, supratrochlear, infratrochlear, and lachrymal nerves, frontal and supra-orbital arteries and nasofrontal vein) pierce the orbital septum, which is connected with the medial palpebral ligament or the lateral palpebral raphé (see below) in the medial or lateral angle of the eye, respectively, and at the same time it closes off the adipose body of the orbit anteriorly, and by it is given an anterior convexity.

THE LACHRYMAL APPARATUS.

To the *lachrymal apparatus* (Figs. 763 to 768, and 771) belong first, the secretory organs or lachrymal glands; second, the *lachrymal lake* (lacus lacrimalis), which is formed by the conjunctiva and collects the tears or *lacrimæ* flowing over the anterior surface of the cornea and through the conjunctival sac at the medial angle of the eye; third, the *lachrymal ducts*, which take up the tears from the lake and conduct them to the *lachrymal sac*, whence they pass through the *nasolachrymal duct* into the nasal cavity.

There may be distinguished a larger superior and a smaller inferior, and, also, accessory lachrymal glands. The *superior lachrymal gland* (Figs. 758, 763, and 771) lies in the lachrymal depression of the frontal bone (see Vol. I., page 61), that is to say, in the lateral corner of the superior wall of the orbit, just below the periorbita, and represents a rather well-defined, flattened, oval gland, whose long axis lies parallel to the border of the orbital cavity. The surface of the gland facing the bone is decidedly convex, that facing the eyeball is concave. The gland is of a grayish-red color, rather soft as to its consistency, and has a distinctly lobular structure. The majority

FIG. 762.—The capsule of Tenon, or fascia of the bulb of the right eye with its openings, as seen after the removal of the eyeball.

Both eyelids have been divided to their bases by a sagittal incision and reflected. * = Inner lip of the muscle-slit.

FIG. 763.—The two tarsal plates of the right eye, the palpebral ligaments, and the lachrymal sac.

The skin and musculature of the lids have been removed and the tendon of the levator palpebræ superioris divided.

FIG. 764.—The lachrymal sac and the lachrymal ducts as seen from in front.

The skin and musculature have been divided, and partly removed and partly reflected. The medial palpebral ligament has been divided.

FIG. 765.—The lachrymal ducts, the lachrymal sac, and the nasolachrymal duct exposed from in front.

Dissection as in Fig. 764, with a piece of the maxilla chiseled away.

of the lobules, however, are rather intimately connected, but, in the posterior part, the orbital fat penetrates deeply into the spaces between the lobules, which are consequently partly isolated in this region.

The *inferior lachrymal gland* (Fig. 771) is only about one-third the size of the superior and lies below it, close to the conjunctival fornix, in the immediate vicinity of the lateral angle of the eye. In contrast to the superior gland it consists of only loosely connected and often almost completely isolated lobules, about twenty to thirty in number. It is separated from the superior gland by a layer of fascia (see above), but, as a rule, has outlets in common with it, the *excretory ducts of the lachrymal glands*, the very fine and narrow ducts of the superior gland receiving the majority of those of the inferior one, although some lobules of the latter also open separately into the lateral portion of the conjunctival fornix. The ducts of the two glands are about ten to fifteen in number. In addition to the main glands there are also *accessory lachrymal glands*, occurring in the conjunctiva and in the eyelids themselves (page 273).

The *lachrymal ducts (canals)* (Figs. 764 and 765) are very narrow, curved canaliculi, which begin at the margins of the upper and lower lids near the medial commissure of the two, between this and the medial extremity of the tarsal cartilage (page 271), as small, almost circular openings, the *lachrymal puncta*. There is a *superior* and an *inferior punctum*, and they lie upon small, low projections of the margin of the lid, the *lachrymal papillæ* (*superior* and *inferior*). They look posteriorly and toward the lachrymal lake (page 272), of which they form the lateral boundary, and when the lids are closed they project into the lake and thus allow the lachrymal puncta to absorb the lachrymal fluid.

The lachrymal ducts themselves are narrow and very thin-walled canaliculi which run in the medial portion of the eyelids, parallel to the periphery of the lachrymal lake. At their commencement on the lachrymal puncta they are at first vertical and then turn so as to run in an almost transverse direction, and, just before this bend, each usually possesses a slight dilatation, the *ampulla of the lachrymal duct*. The transverse part of each canal then passes toward the lachrymal sac, into whose lateral wall both ducts open below the fornix (see below), usually close together and more rarely with a common terminal portion. The orifice of each duct is behind the medial (internal), palpebral ligament (see page 272, and Vol. I., page 179). The lachrymal ducts have no musculature of their own, but are surrounded by fibers of the orbicularis oculi (palpebral portion) (Vol. I., page 179). They lie very close beneath the thin integument of the eyelids, which covers them.

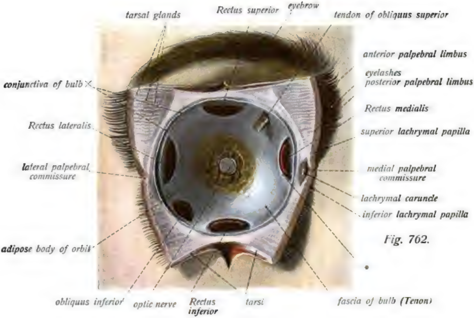

Fig. 762.

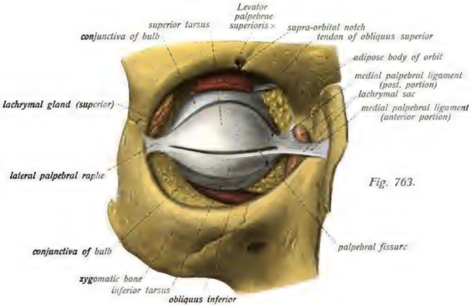

Fig. 763.

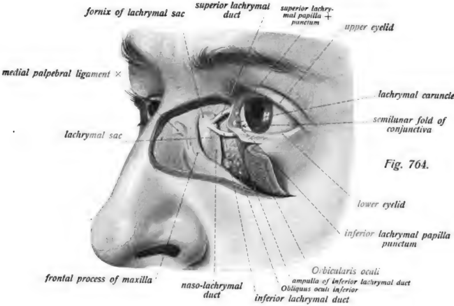

Fig. 764.

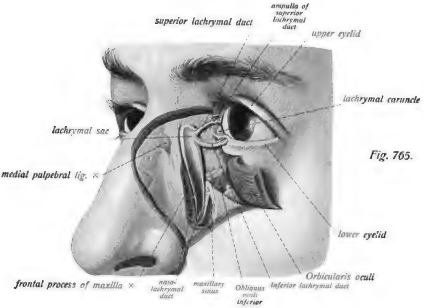

Fig. 765.

The *lachrymal sac* (Figs. 763 to 765) is the upper, moderately enlarged, blind end of the nasolachrymal duct. It lies in a fossa behind the medial border of the orbit (see Vol. I., page 75), and in shape and size corresponds to the fossa. Its upper, slightly tapering, blind end is called *fornix of the lachrymal sac*, and at about 1.5 to 2 mm. below its apex the two ducts (see above) open upon a small projection of the lateral wall. The medial (internal) palpebral ligament spreads out over the lachrymal sac, which is also surrounded by the fibers of the lachrymal portion of the orbicularis oculi (Horner's muscle) (see Vol. I., page 179).

Below, the lachrymal sac is continued into the *nasolachrymal duct* (Figs. 764, 765, and Vol. II., Fig. 424) without a sharp line of demarcation. This duct, as regards its position, length, and boundaries, corresponds exactly to the bony canal in which it lies (see Vol. I., pages 64, 67, and 75). Like this, it opens into the anterior part of the inferior nasal meatus, usually in such a way that the duct penetrates the nasal mucous membrane obliquely for a short distance, thus forming a valvular fold, known as *lachrymal fold* (Hasner's fold). The cleft-like opening of the duct is usually in the horizontal plane, but varies considerably in shape, width, and position.

The lachrymal sac and nasolachrymal duct are lined by a mucous membrane which is not especially folded, but contains glands in the region of the lachrymal sac. The lumen of the latter, when empty, is compressed.

As regards the size of the separate portions of the lachrymal apparatus, the superior gland measures 20 mm. in its longest diameter, is 10 to 12 mm. in width, and 5 mm. thick. The lachrymal punctum of the lower lid has a slightly larger diameter (0.3 mm.) than that of the upper lid (0.2 to 0.25 mm.), and the superior lachrymal duct is a little narrower (but longer) than the inferior, the length of each being about 1 cm. The narrowest point of the ducts is at the lachrymal punctum; their average diameter is 0.6 mm.; that of the ampullæ almost 1 mm. The lachrymal sac is about 12 mm. in length, with an average diameter of about 5 mm. The nasolachrymal duct has a diameter of about 4 mm. (in the sagittal direction, a little less transversely) and an average length of 15 mm.

The blood-vessels of the lachrymal gland come from the lachrymal artery and partly also from the anterior deep temporal artery (see page 28). The lymph-vessels are identical with those of the conjunctiva. The nerves are supplied by the lachrymal nerve.

THE EYELIDS OR PALPEBRAE.

Both eyelids (Figs. 761 to 763, and 766 to 771), the broader, upper one, and the narrower, lower one, are cutaneous folds stretched across the external opening of the orbit and conforming to the form of the anterior (corneal) segment of the eyeball lying behind them, so as to present a distinctly concave posterior and a convex anterior surface.

By their free borders the eyelids bound an almost horizontal opening, the *palpebral rima*, meeting at its medial and lateral ends to form the *medial* and *lateral palpebral commissures*. By the commissures are formed the two angles of the eye, the pointed, arch-like, more exposed *lateral angle*, and the broader, rounder, more deeply seated *medial angle*, with the lachrymal lake. The upper lid bounds the palpebral fissure (*rima palpebralis*) with a distinctly convex border, while the lower one has an almost straight, slightly concave border, and the attached borders of both lids pass over into the adjacent skin, musculature, etc., without any sharp line of demarcation.

FIG. 766.—The right eye, open.
FIG. 767.—The right eye, closed.
FIG. 768.—The right eye widely opened by drawing the lids apart. The eyeball looks toward the temporal side.

In the upper lid the upper border is indicated by a number of strong hairs, the eyebrows or *supercilia*, which are arranged in the shape of an arch, convex upward.

The breadth of the two lids is quite different; that of the upper one is 22 to 25 mm., that of the lower only 11 to 13 mm. The thickness of the two, however, is about the same; in the neighborhood of the free border it is about 3 mm., at the base about double that amount.

When the eye is closed, the longer upper lid covers a much larger portion of the anterior surface of the eyeball than does the lower lid, and it also makes a wider excursion in opening the lids. In the open eye a horizontal through the medial angle of the lids cuts the lower lid below the lateral angle; in the closed eye it passes above this angle; therefore, in the closed eye the whole lower lid and also the lower part of the upper lid, and consequently also the whole length of the palpebral fissure, lies below the horizontal. In the closed eye the free border of the upper lid reaches to the inferior border of the cornea, and between its concave posterior surface and the anterior surface of the cornea there is a narrow, merely capillary space, called the *lachrymal rivus*.

The convex anterior surface of each lid possesses a very fine and thin external skin which shows all the peculiarities of such skin, possessing especially lanugo hairs (of extremely small size, however) and integumentary glands. The dermis of the lids, however, is devoid of fat; only in the base of the lid, which is called the orbital portion in contrast to the thinner lower or palpebral portion, a small amount of adipose tissue makes its appearance. The integument of the lids, even when the palpebral rima is closed, possesses transverse folds, and when the lids are open a stronger transverse fold occurs at the base of each, the *orbitopalpebral sulcus*. The concave posterior surface of the lids is covered by the palpebral conjunctiva, which is firmly united with the lid, and at the free border of each lid the conjunctival and epidermal surfaces blend. The free border is rather a narrow surface, and is continuous by a usually blunted anterior border, the *anterior palpebral limbus*, and a usually sharp posterior border or *posterior palpebral limbus* into the anterior and posterior surfaces respectively of the lids. The anterior palpebral limbus bears strong hairs called eyelashes or *cilia*, which are inserted in an oblique direction, and thus stand with their roots pointing backward and upward, or downward in the lower lid, through the epidermis and dermis of the lid into the musculature (see below). They stand close together, arranged in two or three rows, and in the upper lid, where they are stronger and longer, they are more numerous (one hundred and forty to one hundred and fifty) than in the lower lid (fifty to seventy-five). When the lids are closed the cilia touch one another in such a way as to be partly interlocked. Between them open, in addition to the sebaceous glands which they possess, some modified sudoriparous glands, the *ciliary glands*.

The free borders of the lids are not quite horizontal to the surface of the lid, but are slightly beveled, so that the anterior limbus of the upper lid projects a little further downward than the posterior, and the reverse is true of the lower lid. The consequence is that the borders of the lids fit upon one another when the lids are closed.

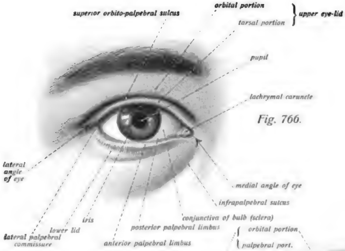

Fig. 766.

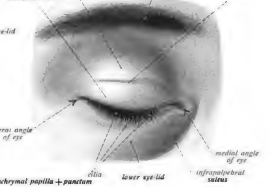

Fig. 767.

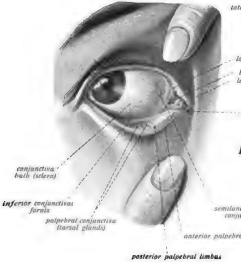

Fig. 768.

The framework of the lids is made up of a stiff, connective-tissue plate, almost cartilaginous in consistence, which is curved so as to correspond with the curvature of the lid, and forms the *tarsal plate* or *tarsus*. This, in general, corresponds closely to the form of the lid, so that the broader upper lid has a broader tarsus than the lower one. The greatest breadth of the superior tarsus lies about its middle and is about 10 mm., that of the inferior tarsus being only about half as much; its thickness is 0.75 mm. to 1 mm., and its length 20 mm. Both tarsal plates have

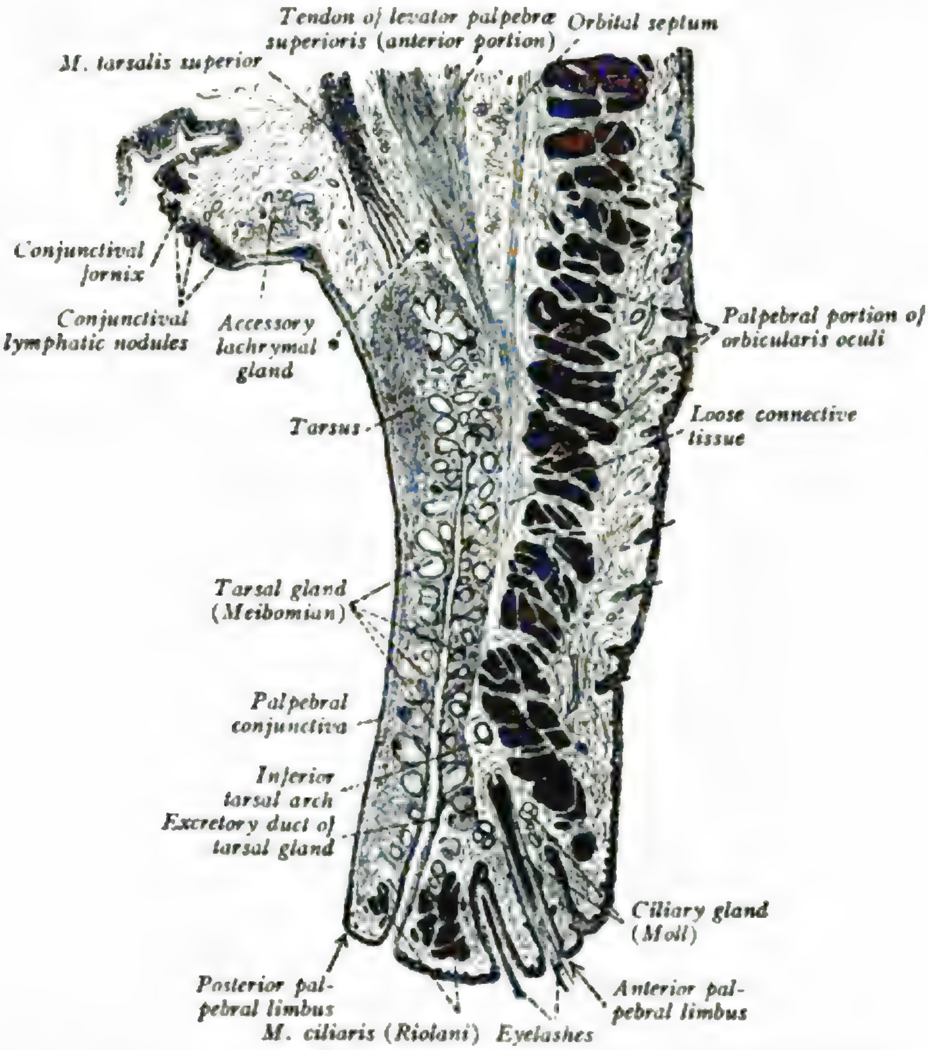

FIG. 769.—A vertical section of the upper eyelid (enlarged). * Superior tarsal arch.

an irregular semilunar shape; their medial ends being broader than the lateral, and the upper edge (the lower in the lower lid) does not reach to the base of the lid, but ends a little before reaching it by being marked off rather sharply from the adjacent tissue. The anterior surface of the tarsus is separated from the integument of the lid by the palpebral part of the orbicularis oculi (see below and Vol. I., 179), while at the posterior surface it is closely adherent to the connective tissue of the palpebral conjunctiva; indeed the tissue of the tarsus is everywhere directly

FIG. 770.—The anterior aspect of the orbital septum of the right eye.
FIG. 771.—The eyelids and the lachrymal glands as seen from behind.
* = Fatty tissue.

connected with the neighboring connective tissue. Along the whole length of the upper border and the anterior surface of the superior tarsus the tendon of the levator palpebræ superioris is inserted.

Between the tarsal plate and palpebral conjunctiva of both eyelids, and extending throughout their entire width, are peculiarly modified sebaceous glands known as the Meibomian or *tarsal glands.* They consist of a central duct, completely surrounded by vesicular glandular alveoli, and lie in a single layer, parallel to one another, in the substance of the tarsus itself, their excretory ducts opening at short intervals from one another on the posterior palpebral limbus. The number of glands in the upper lid is thirty to forty, in the lower only twenty to thirty, and since they always extend the entire height of the tarsus they are, therefore, longer in the upper than in the lower lid, and longest in the middle part of the upper lid. Since they produce a sebaceous secretion known as *palpebral sebum,* they appear on the conjunctival surface of the lid as yellowish-white structures, even in the living. The length of the tarsal plate is less than that of the lid, since the plate reaches neither to the lateral nor the medial palpebral commissure, that part of each lid which bounds the lacus lacrimalis being entirely destitute of tarsal tissue, so that neither the lachrymal puncta nor canals (page 268) are associated with the tarsus.

At the angles of the lids the tarsi, as well as the musculature of the lids, are connected with the *medial palpebral ligament* and the lateral palpebral raphé. The former represents a tendinous arch which arises from the frontal process of the maxilla and extends by an anterior, narrower limb, which is visible through the skin, transversely over the anterior surface of the lacus lacrimalis, while a broader posterior limb makes a curve around the lacus lacrimalis to the posterior lachrymal crest of the lachrymal bone. The medial palpebral ligament is interwoven with the orbital septum (see page 267) and serves as a place of attachment for the medial ends of both tarsi and also for the fixation of the medial angle of the lids, and gives origin to the fibers of the palpebral portion of the orbicularis oculi. The *lateral palpebral raphe* is not really a tendon, but a tendinous band interwoven with the musculature of the orbicularis oculi and the orbital septum, and having attached to it the lateral ends of the tarsi.

The musculature of the eyelid (Fig. 769) consists of the palpebral portion of the orbicularis oculi. Its fibers surround the palpebral fissure in an arch-like manner and lie between the outer skin of the lid and the anterior surface of the tarsus. The bundles lying nearest the free border of the lid are separated from the main part of the muscle by the roots of the eyelashes (see above) and are known as the *ciliary muscle (of Riolan).* Separate groups of fibers also surround the ducts of the tarsal glands. In addition to the striated musculature there are also smooth muscle fibers at the base of the eyelids, which are inserted by elastic tendons into the upper or lower border of the tarsi and are known as the *superior* and *inferior tarsal muscles.* The former is a direct continuation of the levator palpebræ superioris.

The lachrymal lake (*lacus lacrimalis*) is that part of the medial angle of the eye which is bounded by the medial portions of the two lids and by a conjunctival fold, the *semilunar fold*

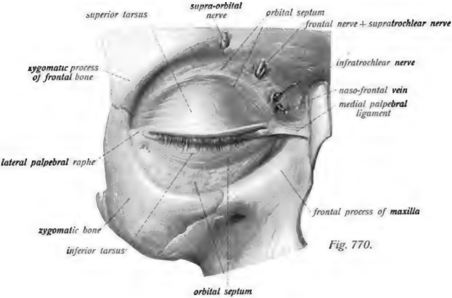

Fig. 770.

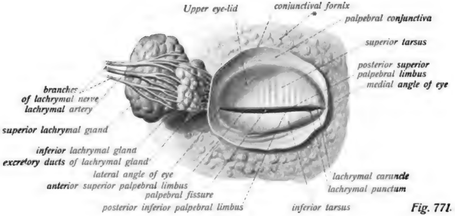

Fig. 771.

of the conjunctiva. At the bottom of the lake is a low, reddish projection covered with sebaceous glands and very fine, woolly hairs, the *lachrymal caruncle.* The portions of the lids which bound the lachrymal lake are destitute of the tarsal tissue and sebaceous glands, but contain, on the other hand, the lachrymal ducts (see page 268). At the border of the lid the limit of the lake is indicated by the position of the lachrymal papilla and punctum, and by the border of the lid possessing at this point a distinct bend.

As regards the blood-vessels of the eyelids, the arteries are the medial and lateral palpebral arteries. The former are the stronger and are branches of the frontal artery; the latter arise from the lachrymal artery (see page 31). The arteries of the medial and lateral halves of the lid form in front of the tarsus; in the part of the lid adjoining the palpebral fissure, an arched anastomosis known as the *superior* and *inferior tarsal arch.* The veins correspond to the arteries and open largely into the veins of the face, and the lymphatics course together with those of the conjunctiva (see below). The nerves of the eyelids arise from the first and second branch of the trigeminal. The upper lid is supplied by the first or ophthalmic branch (lachrymal, supratrochlear, infratrochlear nerves), the lower mainly by the palpebral branches of the infra-orbital and also by the zygomaticofacial branch of the zygomatic nerve.

The eyelids develop as simple folds of the epidermis which gradually grow over the cornea and finally meet and are fused together by the union of the epithelium of the borders, a condition which persists until shortly before birth.

THE CONJUNCTIVA.

The *conjunctiva* (Figs. 761, 762, 766 to 769, and 771) is a mucous membrane which, as a direct continuation of the epidermis, lines a flat sac, the conjunctival sac, lying between the posterior surface of the lids and the anterior surface of the eyeball, and thus being bounded by a convex and a corresponding concave surface, and enclosing only a narrow space, the lachrymal rivus (see page 270). The portions of its wall which cover these surfaces are called the *conjunctival tunics of the eyelids* and *of the eyeball*, and pass over into one another at the base of the lids, forming the *superior conjunctival fornix* in the upper lid and *inferior conjunctival fornix* in the lower one.

At the free border of the lid the palpebral conjunctiva is continued into the epidermis without showing any line of separation, and throughout the whole height of the tarsus it covers the posterior surface of the lid as a smooth skin, closely connected with the tarsus, being separated from the tissue of the lid where the tarsus is lacking by areolar tissue and being, therefore, movable. In the region of the fornix of the conjunctiva small glands less than 1 mm. in diameter, the *conjunctival mucous glands*, occur, lying closely packed in the lateral angle of the eye at the level of the lachrymal gland and quickly decreasing in number toward the medial angle; they occur but rarely in the inferior fornix. According to their function they may be regarded as accessory lachrymal glands. Furthermore, in the region of the fornix small conjunctival lymph-nodes occur or, in some cases, only diffuse accumulations of lymph tissue.

The conjunctiva of the bulb extends from the fornix of the conjunctiva to the border of the cornea, where it ends by a flat swelling, the *conjunctival limbus*, in such a way that its epithelium passes over uninterruptedly into the corneal epithelium, and some connective tissue lamellæ are continued from it into the proper substance of the cornea. The conjunctival sac, therefore, is not bounded by the conjunctiva at the cornea, but this latter structure extends directly into the space. The conjunctiva of the bulb is separated from the anterior part of the sclera, which it covers by a loose tissue, and can easily be removed from it. At the medial angle of the eye it forms a semilunar fold, concave laterally, the *semilunar fold of the conjunctiva*, whose relations

to the lachrymal sac have already been mentioned. Furthermore, there is formed in this situation the low, granular lachrymal caruncle (see page 273) which also must be regarded as a formation of the conjunctiva of the bulb. In the open eye, also, it is not altogether freely exposed, but is partly hidden by the lower lid. Its granular appearance is due to the sebaceous glands * lying in it.

The blood-vessels of the conjunctiva are, first, the same as those of the eyelids, and secondly, twigs from the muscular branches of the ophthalmic artery which pass as episcleral vessels to the conjunctiva. The numerous superficial vessels—especially the smaller veins—give a reddish color to the conjunctiva. The lymphatics of the conjunctiva and of the lids are divided into those of the integument of the lid and those of the conjunctiva; both sets are united and, by means of superficial and deep lymph-vessels, separated by the orbicularis oculi, conduct partly into the lymph-nodes of the parotid region and partly to those of the submaxillary region. The nerves are the same as those of the lids.

THE AUDITORY ORGAN.

The auditory organ is for the most part enclosed in the temporal bone of the cranium (see Vol. I, page 54) and may be divided into three main parts:

1. The *internal ear* is formed by the so-called labyrinth, and of this only the *membranous labyrinth*, which bears the end apparatus of the auditory nerve is the real sound-perceiving part of the organ, the *osseous labyrinth* being only its bony envelope. The entire inner ear lies in the petrous portion of the temporal bone.

2. The *middle ear* is mainly formed by a cavity in the temporal bone, the *tympanic cavity*, which contains air. Its most important parts are a sound-conducting apparatus in the form of the *auditory ossicles* and a communication with the pharynx by the *tuba auditiva*. It is separated from the external ear by the *tympanic membrane*.

3. The *external ear* is the sound-receiving part of the auditory organ and consists of the *external auditory meatus* and the *auricle*.

The Internal Ear.

THE MEMBRANOUS LABYRINTH.

The *membranous labyrinth* (Figs. 772 to 775) is a system of thin-walled branched canals filled with a liquid, the so-called *endolymph*. The two saccules of the endolymphatic canal system, which lie in the vestibule of the bony labyrinth, are known as the vestibular saccules (*sacculus* and *utriculus*), and are directly connected with one another by a rather narrow canal, the *utriculosaccular duct*, which also communicates with the *endolymphatic duct*, arising from the saccule. From the larger of the two saccules, the *utriculus*, three semicircular canals, the *semicircular ducts*, arise, while a spiral canal, the *cochlear duct*, is in communication with the smaller anterior saccule, the *sacculus*, by a short, narrow canal, the *ductus reuniens*.

The endolymphatic cavities lie in corresponding osseous cavities of the bony labyrinth (see below), but the latter do not exactly correspond in shape with the ducts and saccules which they contain; the ducts and saccules do not fill their bony cavity, but a space, the *perilymphatic space*, remains between the bony and the membranous portions of the labyrinth and is also

* In older people there often occurs an accumulation of adipose tissue behind the conjunctiva in the region of the semilunar fold forming what is known as a *pinguecula*.

filled with a liquid, the *perilymph*, and may, therefore, be regarded as a lymph-space. The endolymph and perilymph are completely separated from one another.

The larger vestibular saccule, the ***utriculus*** (Figs. 772 to 774), is an elongated spherical, slightly flattened, thin-walled sac, lying in the elliptic recess of the labyrinth (see below), and is loosely attached to the vestibular wall by connective tissue fibers (ligaments of the saccules). Its attachment is somewhat stronger at the place where the nerve passes from the wall of the labyrinth into it. An oval spot on its medial wall, about 2 mm. in size, is characterized by a special modification of its epithelium and is termed the ***macula acustica of the utriculus;*** on account of the deposition upon it of fine crystals of lime salts, the otoliths (*otoconia*), it has a whitish appearance.*

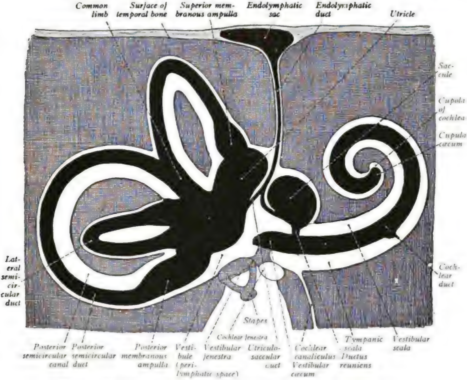

FIG. 772.—The plan of the membranous labyrinth. The endolymphatic spaces are black.

The membranous *semicircular ducts* (Figs. 772 to 774) which arise from the utriculus are

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* For the finer microscopic structure of the membranous labyrinth see the Sobotta-Huber *Atlas and Epitome of Histology*.

FIG. 773.—The right membranous labyrinth with the branches of the auditory nerve isolated (somewhat diagrammatic). (Enlarged seven times.)

* = Utriculo-ampullary branch of the vestibular nerve.

FIG. 774.—The right membranous labyrinth with the efferent nerves partly exposed. The cochlea has been opened from the side (somewhat diagrammatic). (Enlarged seven times.)

** = Commencement of the basal turn; + * = sacculo-ampullary branch of the vestibular nerve.

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very thin-walled endolymphatic canals, oval or elliptic on cross-section, and only partly (about one-fourth to one-fifth) fill the cavity of the corresponding bony canals, lying eccentrically in them so that they are in contact with the inner surface of the bony canal on its convex side. Elsewhere they are loosely connected with the periosteum on the inner surface of the bony canal by connective tissue fibers (the duct ligaments). As with the bony canals (see below), so also there is a *superior*, a *lateral*, and a *posterior semicircular duct*. (Their position will be described below in connection with the bony canals.) Each duct at the one end possesses a large almost spherical enlargement, the *membranous ampulla*, where it opens into the utriculus, the *superior ampulla* being at the anterior end of the superior semicircular duct, the *posterior* one at the inferior end of the posterior duct, and the *lateral* at the anterior end of the lateral duct. In the interior of each ampulla is an obliquely placed, semicircular fold, called the *crista of the ampulla*, which is in connection with the ampullary nerve and corresponds externally to a furrow, the *ampullary sulcus*, which serves for the entrance of the nerve. The sulcus and crista lie on that wall of the membranous ampulla which corresponds to the convex side of the canal, and the ampullæ differ from the ducts proper in that they almost fill the bony ampullæ. Corresponding to the osseous canals (see below) only the lateral duct has two openings into the utriculus, the superior and posterior ducts opening by separate ampullæ at one end and at the other by a very narrow, common limb.

The *sacculus* (Figs. 772 to 774) is the smaller of the two vestibular sacculi, lies in the spherical recess of the vestibule (see below), and has the shape of a flattened sphere. In it also, as in the utriculus, there is an *macula acustica of the sacculus* in connection with the terminal ramifications of a corresponding nerve. From the lower, slightly narrowed end of the sacculus the very slender *ductus reuniens* (duct of Hensen) passes to the cochlea. The sacculus lies with its lateral wall about opposite to the fenestra of the vestibule (see below), but it is separated from this and from the foot of the stapes by a large, perilymphatic space, since sacculus and utriculus together occupy only a little more than half the cavity of the (bony) vestibule.

The *cochlear duct* (Figs. 772 to 775) is a narrow, spiral canal, triangular on cross-section, situated in the spiral canal of the cochlea (see below) and making two and a half convolutions about the cochlear axis, diminishing a little in caliber toward the apex of the cochlea. It begins with a blind sac, the *vestibular cæcum*, which is situated in the vestibule in the cochlear recess (see below), and receives the ductus reuniens. A similar blind pouch, the *cupular cæcum*, occurs also at the tip of the duct, and in this region the duct, as well as the cochlea itself, is elliptic on cross-section. The cochlear duct has a decidedly different relation to the perilymphatic spaces than the other parts of the labyrinth, for the cochlear canal contains two perilymphatic spaces, separated by the cochlear duct and the spiral lamina of the cochlea (see below), and known as the *tympanic* and the *vestibular scala*. The two scalæ communicate with one another at the *helicotrema* (see below) and correspond to the similarly named demicanals of the bony cochlea,

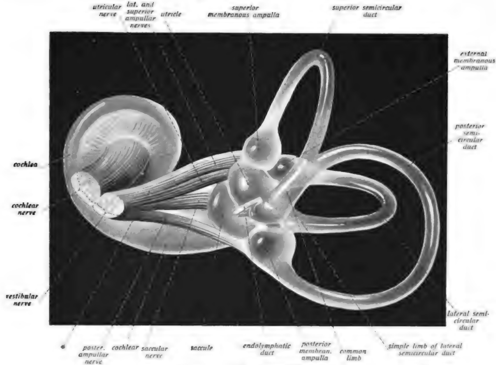

Fig. 773.

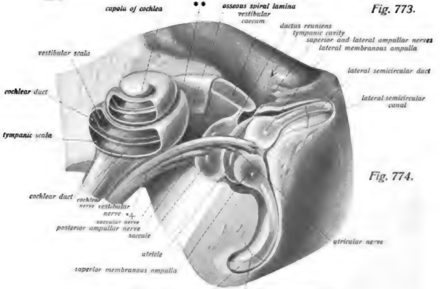

Fig. 774.

the tympanic scala completely, and the vestibular scala in such a way that its lower portion is occupied by the cochlear duct (Fig. 775). The cochlear fenestra of the tympanic scala is closed by a delicate membrane, the *secondary tympanic membrane.*

The cochlear duct is bounded in the following manner. In the first place the edge of the spiral osseous lamina (see below) is united to the opposite wall of the cochlea by the ***membranous spiral lamina***, which is inserted into a periosteal thickening, the so-called ***spiral ligament*** (in the region of the basal convolution it is inserted into the secondary spiral lamina—see below). Thus the scalæ which communicate at the free border of the spiral osseous membrane in the bony cochlea are completely separated from one another. Furthermore, an extremely thin

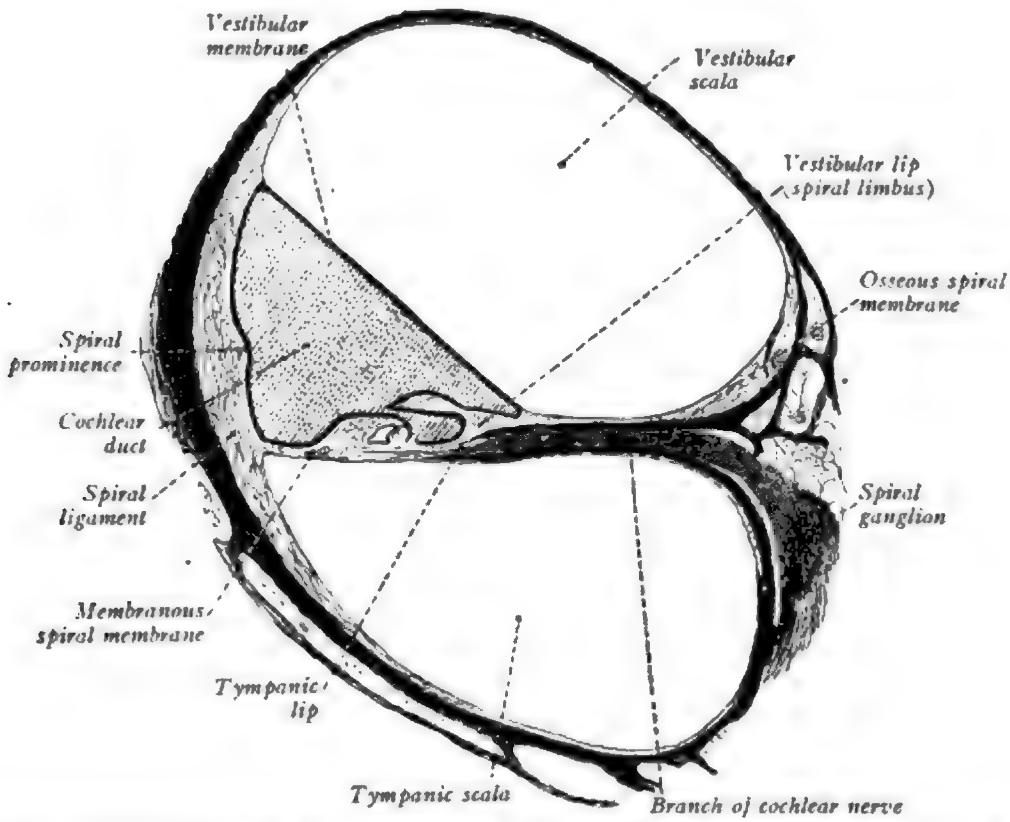

FIG. 775.—A cross-section of a turn of the cochlea (diagrammatic). The space occupied by the cochlear duct is dotted.

membrane, the *vestibular membrane* (membrane of Reissner), passes from a connective-tissue thickening of the surface of the osseous spiral membrane which faces the vestibular scala, the ***spiral limbus***, toward the lateral wall of the cochlea, and thus separates the triangular cochlear duct from the true perilymphatic vestibular scala. Therefore, the cochlear duct is bounded first on the side of the tympanic scala by the membranous spiral lamina, secondly on the side of the vestibular scala by the vestibular membrane, while the third wall of the duct is not in relation to perilymph, but is in direct contact with the lateral wall of the bony cochlear canal. Upon the membranous spiral lamina we find the so-called *spiral organ* (organ of Corti), for the structure of which see the Sobotta-Huber *Atlas and Epitome of Histology.*

FIG. 776.—A cast of the right bony labyrinth as seen from the outer side and in front. (Enlarged seven times.)

* = Exposed commencement of the basal turn.

FIG. 777.—A cast of the right bony labyrinth as seen from the inner side and behind. (Enlarged seven times.)

* = Basal turn; ** = middle turn.

FIG. 778.—A cast of the right bony labyrinth as seen from below. (Enlarged seven times.)

* = Exposed commencement of the basal turn of the cochlea.

FIG. 779.—The right internal auditory meatus as seen from the inner side after chiseling away a portion of its posterior wall. (Enlarged about three times.)

** = Cut surface of the bone.

FIG. 780.—The same preparation viewed from the inner side and from in front.

The *endolymphatic duct* and *sac* (Fig. 772) are very rudimentary structures in man, while in lower animals they have a relatively much larger development. The endolymphatic duct arises from the lateral portion of the sacculus, and extends as an extremely fine canal filled with endolymph through the entire length of the vestibular aqueduct (see Vol. I., page 55) to below the dura mater, where it ends blindly with a slight swelling, the endolymphatic sac. Soon after its exit from the sacculus it receives at an acute angle an even more slender duct from the utriculus, the *utriculosaccular duct* (see page 274).

THE OSSEOUS LABYRINTH.

The *osseous labyrinth* (Figs. 776 to 790) is the cavity in which the membranous labyrinth is situated. Since the latter is separated from the inner surface of the bony cavity by perilymphatic spaces, the bony labyrinth is considerably more spacious than the membranous one, but otherwise it repeats all the out-pouchings, ducts, etc., of the membranous part. An exception to this occurs in connection with the vestibular saccules, both of these lying in a common osseous cavity, the *vestibule*, which also contains the vestibular cæcum of the cochlear duct, the beginning of the endolymphatic duct and the utriculosaccular duct.

The wall of the bony labyrinth is formed of extremely firm, compact bone, which in the newly born is quite distinctly differentiated from the spongiosa of the temporal bone, but only indistinctly so in the adult. It also contains a number of canals which conduct the nerves and vessels for the membranous labyrinth. The bony labyrinth lies with its medial surface facing the internal auditory meatus and its lateral surface toward the tympanic cavity, where several projections (the promontory, prominences of the lateral semicircular canal, see page 285) are produced by the structures of the labyrinth. Its whole length is about 20 mm., and its long axis stands obliquely to the pyramid of the temporal bone in such a way that the anterior part of the labyrinth, the cochlea, looks at the same time downward and medially, and the posterior part, the semicircular canals, upward and laterally (Fig. 781).

THE VESTIBULE.

The *vestibule* (Figs. 776 to 778 and 782 to 785) is the middle and at the same time the roomiest part of the bony labyrinth, and lies between the semicircular canals and the cochlea. It is almost oval, since its posterior part is broader than the anterior, and the inner surface is for

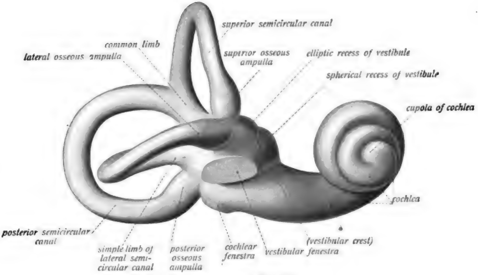

Fig. 776.

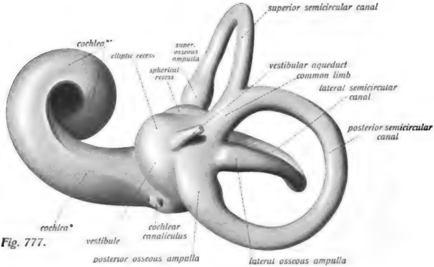

Fig. 777.

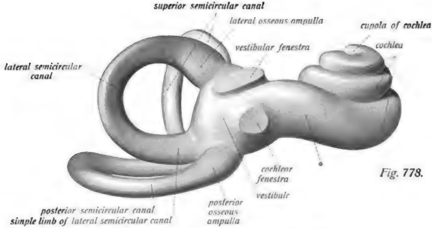

Fig. 778.

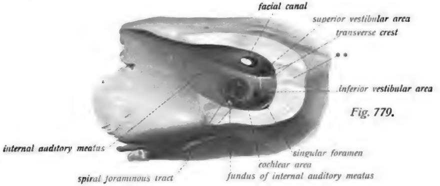

Fig. 779.

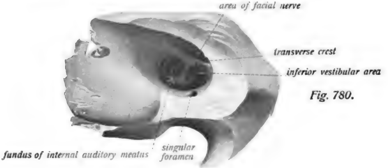

Fig. 780.

the most part smooth. Of its walls, the medial separates it from the internal auditory meatus, and the lateral from the tympanic cavity (see page 285), and through an aperture in this wall, the *vestibular fenestra*, the cavity of the vestibule, communicates with the tympanic cavity.

On the medial vestibular wall is an almost vertical, low ledge, the *vestibular crest* (Figs. 785 and 790), which separates a rather round, small, anterior (and inferior) depression, the *spherical recess*, from a larger posterior (and superior) elongated one, the *elliptic recess*. The former contains the sacculus, the latter the utriculus (see page 275). The vestibular crest terminates superiorly in a point, the *vestibular pyramid*, and inferiorly in two limbs which bound a shallow groove, the *cochlear recess* (Fig. 785), lying on the inferior wall of the vestibule, close to the beginning of the osseous spiral lamina (see below). In this recess lies the beginning portion of the cochlear duct, the vestibular cæcum (see above).

In the walls of the vestibule the following apertures are found. On the lateral wall, lying obliquely, is the low kidney-shaped *vestibular fenestra* (foramen ovale), convex superiorly and concave inferiorly. For the entrance of the branches of the acoustic nerve (see page 283) the lateral wall has a number (about 15) of small foramina, through which the nerve branches for the macula acustica of the sacculus pass, the region in which they occur being known as the *medial cribriform macula* (Fig. 790). Furthermore, a similar region, the *superior cribriform macula*, at the upper end of the vestibular crest (upon the pyramid), transmits the branches of the utricular nerve, while the *inferior cribriform macula* (Fig. 785), the smallest of the three and through which the nerve passes that enters by the foramen singulare (see below), lies next to the ampulla of the posterior semicircular canal, that is to say, on the inferior wall of the vestibule. Five openings of semicircular canals lead into the posterior portion of the vestibule (elliptic recess); three are ampullary openings, two are simple. The latter lie on the medial wall of the vestibule, those of the lateral canal below the common crus (see below), while the ampulla of the posterior canal lies on the inferior wall and the two anterior ampullæ in close proximity at the boundary of the posterior and lateral walls.

Furthermore, the spiral canal of the cochlea opens into the anterior wall of the vestibule, and on the medial wall of the elliptic recess the vestibular aqueduct enters by an elongated, narrow slit.

THE OSSEOUS SEMICIRCULAR CANALS.

The *osseous semicircular canals* (Figs. 776 to 778, 781 to 786, and 790) contain the membranous semicircular ducts, and like these consist of two vertical canals and one horizontal. Each describes about two-thirds of the circumference of a circle and is somewhat flattened in the direction of its surfaces of curvature, thus being laterally compressed. Each canal has two openings into the vestibule, a wider, ampullar opening* and a narrower, simple one. Since the two vertical canals have a common limb for a short distance, by means of which they empty into the vestibule, the latter shows only five openings for the canals (see above). One of the vertical canals stands perpendicular to the axis of the pyramid of the temporal bone, that is to say, parallel to its transverse diameter, and is called the superior vertical or *superior semicircular*

* The bony ampullæ are comparatively narrow and represent only moderate swellings of the canal. Consequently the membranous ampulla almost completely fills the bony one, while the membranous duct, which is much narrower than the ampulla, occupies only a part of the cavity of the bony canal.

canal. It is at the same time the highest canal, and at the point of its greatest curvature reaches almost to the cerebral surface of the pyramid, where it produces the arcuate eminence (see Vol. I, page 54). At its anterior end it begins with an ampullar limb at the superior osseous ampulla, which lies close to the tympanic cavity and the facial canal, and with the following canal forms the *common limb* at its posterior end. According to its width and length it occupies a middle position, that is to say, it is narrower and longer than the lateral canal, but a little wider and shorter than the posterior one.

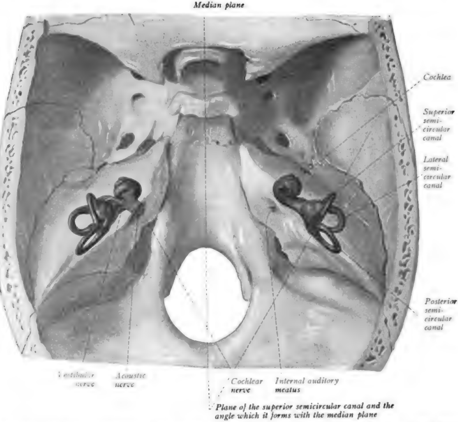

FIG. 781.—The two bony labyrinths in their natural reciprocal relations. Upon the left side the efferent nerves have also been represented (diagrammatically).

The second vertical canal, the *posterior semicircular canal*, lies, as its name implies, almost parallel to the posterior surface of the pyramid of the temporal bone and perpendicular to the

superior canal, its greatest curvature being backward and downward. It begins in the vestibule with an ampullar limb and a posterior osseous ampulla, which opens into the inferior wall of the vestibule at a considerable distance from the other two ampullæ. Its upper end unites with the posterior end of the superior canal to form the common crus. The posterior canal lies deeper than the superior; of the three it has the most pronounced curve, and is consequently the longest, but also the narrowest.

The horizontal or *lateral semicircular canal* lies horizontally in the angle made by the other two, and is by far the shortest, but also the widest. It has two separate openings into the vestibule; the ampullar limb begins as the anterior portion of the canal by means of the lateral osseous ampulla, which lies next to the superior ampulla and produces the prominence of the lateral semicircular canal (see page 286); the posterior portion forms a simple limb, which opens into the vestibule below the common limb. The point of greatest curvature of the canal looks laterally and a little posteriorly.

THE COCHLEA.

The *cochlea* (Figs. 775 to 778, 781 to 787, and 789) is formed by the *spiral canal of the cochlea*, a spiral canal having two and a half convolutions and lying in an especially firm and hard, compact portion of the pyramid of the temporal bone. The spiral canal winds around an axis known as the *modiolus*, composed of spongy bone substance and having the shape of a low cone, hollow in the centre.

In the cochlea there may be recognized the broad (7 to 8 mm.) *base* and the *cupola*, a blind end lying opposite the base, at the apex of the cochlea. The latter is directed toward the anterior part of the tympanic cavity and lies close to the medial wall of the tuba auditiva, while the base faces the internal auditory meatus. Therefore, the axis of the cochlea is oblique, somewhat perpendicular to the posterior surface of the pyramid, and is directed from above, behind and laterally, downward, anteriorly and medially. Its length is about 4 to 5 mm.

The bony cochlear canal begins at its *vestibular aperture* in the anterior wall of the vestibule (see below), and by means of the *cochlear fenestra* it communicates with the tympanic cavity, whose medial wall it bulges out to form the promontory (see page 285). Immediately adjacent to the crest of the cochlear fenestra (see page 286) the cochlear canaliculus (see Vol. I, page 66) arises from the cochlear canal, which continues onward for a short distance, only moderately curved, and then winds spirally about the cochlear axis. As it approaches the cupola of the cochlea the canal becomes gradually narrower, so that a wide, basal convolution, a narrower, middle one, and a very narrow (half) apical convolution may be distinguished. The middle convolution rests upon the basal one and rises above its level; while the apical convolution is inside of the middle one and scarcely projects beyond it.

The modiolus, like the cochlea itself, has a *base* excavated by the *cochlear area* (see below), which is a depression lying on the floor of the internal auditory canal. It possesses spirally arranged foramina intended for the entrance of cochlear nerve fibers and forming the *spiral foraminous tract*. The axis of the modiolus coincides with the axis of the whole cochlea, but is comparatively shorter than it, being but little more than half as long. The basal convolution of the cochlear canal winds about the hollow base of the modiolus, but, in the region of the middle convolution

FIG. 782.—The right bony labyrinth seen from the inner side and from behind. (Enlarged six times.)

FIG. 783.—The right bony labyrinth seen from the outer side and from in front. (Enlarged six times.)

* Apical turn of cochlea. ** Middle turn of cochlea. *** Basal turn of cochlea.

FIG. 784.—The right bony labyrinth seen from in front. (Enlarged seven times.)

The semicircular canals and the greater portion of the spiral canal of the cochlea have been filed open.

FIG. 785.—The left bony labyrinth. (Enlarged seven times.)

Preparation as in Fig. 784, but the vestibule and the cochlea have been opened as far as the cupola.

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the inner part of the modiolus consists of a spongy bone substance traversed by narrow canals, the *longitudinal canals of the modiolus* (Fig. 787), which do not extend to the tip of the modiolus, but end blindly at a varying height, the longest canal, which lies in the axis of the modiolus, reaching almost to the cochlear cupola. The modiolus stops at the end of the second (middle) convolution and passes over into a bony lamella, the *lamina of the modiolus* (see below), and around the modiolus also a delicate, bony lamella, known as the *bony spiral lamina* (Figs. 785 to 787), winds in a spiral manner and produces an incomplete division of the cochlear duct, the division being completed by the membranous spiral lamina (see page 277). The width of this extremely thin bony plate is about half of the transverse diameter of the cochlear convolution at any point, the width of the plate decreasing continually toward the cochlear cupola.* At the upper end of the modiolus the osseous spiral lamina becomes free and curves around the lamina of the modiolus in the form of a bent point, the *hamulus of the spiral lamina* (Fig. 786). Thus, a semilunar opening called the *helicotrema* is formed between the lamina of the modiolus and the hamulus of the spiral lamina. The lower *tympanic scala* begins at the crest of the cochlear fenestra and courses up spirally below the osseous spiral lamina, while the upper *vestibular scala* begins at the vestibular recess and passes above the spiral membrane to the helicotrema. In the region of the basal convolution the tympanic scala is considerably larger than the vestibular scala, but it becomes continually narrower toward the cupola of the cochlea and the vestibular scala correspondingly wider. The two scalæ are continuous in the macerated cochlea at the free border of the bony spiral membrane (tympanic lip†) throughout the entire length of the spiral canal; while in the fresh condition they are separated by the membranous lamina (see page 277) and communicate only at the helicotrema. At the base of the osseous spiral lamina is a spirally running canal, the *spiral canal of the modiolus*, in which lies the spiral ganglion (see below).

As regards the walls of the cochlear canal, they are formed by the bony cochlea on one side, *i. e.*, externally and partly superiorly and inferiorly, and on the other, internally and partly inferiorly, by the external surface of the modiolus. They are for the most part smooth, but in the first portion of the basal convolution, on the lateral wall of the canal opposite the osseous spiral lamina, there is a bony ledge, the *secondary spiral membrane* (Fig. 787), which gradually decreases in size and is fused, for a short distance, with the osseous spiral lamina at the vestibular aperture of the cochlea. Since the apical half convolution of the cochlea practically does not project beyond the level of the middle convolution the position of the bony partition between

* Consequently the relative width of the membranous spiral lamina increases continually toward the cochlear cupola.

† In addition to the tympanic lip there is also a *vestibular lip* which is produced by a periosteal thickening of the cochlear duct, and does not belong to the osseous spiral lamina.

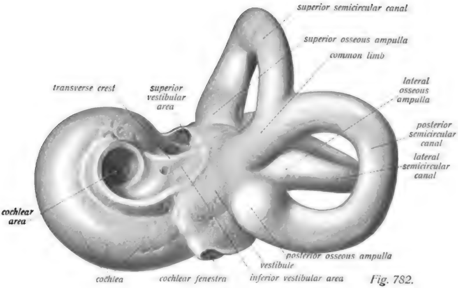

Fig. 782.

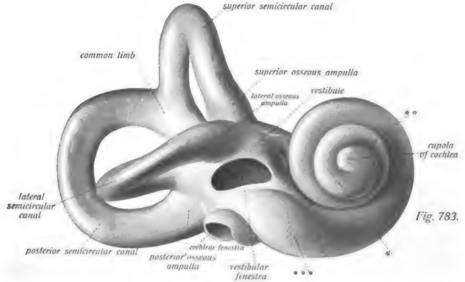

Fig. 783.

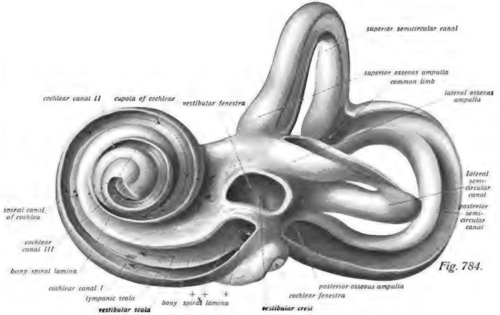

Fig. 784.

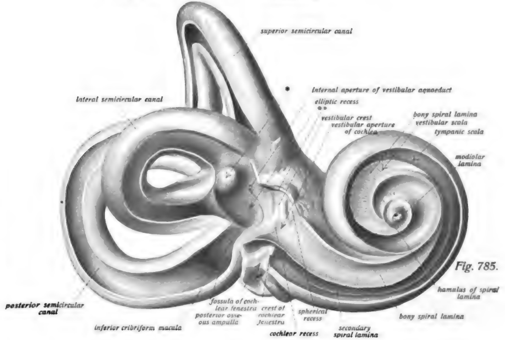

Fig. 785.

the convolutions of the cochlear canal changes in the upper part of the cochlea. In the region between the basal and middle convolutions the partition is thick and is vertical to the axis of the modiolus, but in the middle convolution it becomes more inclined, and in the apical convolution it becomes so steep that it finally comes to lie almost in the direct line of the cochlear axis and has the form of a half funnel-shaped lamina, concave toward the apical and convex toward the middle convolution, known as the *lamina of the modiolus* (Figs. 786 and 787). It extends from the apex of the modiolus to the cochlear cupola, and its curved free border, together with the hamulus of the spiral lamina, forms the helicotrema.

THE INTERNAL AUDITORY MEATUS.

The *internal auditory meatus* (Figs. 779 and 780) begins at the internal auditory pore on the posterior surface of the pyramid of the temporal bone and from this passes laterally, as a rather narrow canal, elliptic in cross-section, into the substance of the temporal bone, ending at the *fundus of the internal auditory meatus*. Through the internal auditory foramen the acoustic, facial, and intermediate (see page 187) nerves and the internal auditory artery and vein (see page 86) enter the temporal bone, and in the meatus the two main nerve-trunks, the acoustic and facial, separate, the intermediate nerve blending with the latter.

At the fundus of the internal auditory meatus is an almost transverse, slightly curved, bony ridge, the *transverse crest*, which separates a superior smaller depression from an inferior larger one, the former being again divided by a bony ridge into an anterior and a posterior portion. At the anterior superior portion of the fundus is the *facial canal*, as a rather large, round foramen; this portion of the fundus is, therefore, called the *area of the facial nerve*. The superior posterior portion is the *superior vestibular area;* it has a number of small holes, which lead to the superior cribriform macula of the vestibule (see page 279) and contain the branches of the utricular nerve and of the superior and lateral ampullary nerves.

That portion of the fundus which lies below the transverse crest is divided into the posterior *inferior vestibular area* and the anterior *cochlear area*. The latter presents a number of foramina, which lie in the hollow base of the cochlear axis (see page 281) and are arranged spirally, representing the spiral foraminous tract, while the inferior vestibular area transmits fine branches to the middle cribriform macula of the vestibule (for the saccular nerve). Finally, there is an additional separate, moderately large, round foramen, which does not lie in the fundus proper, but rather toward the posterior wall of the meatus; it is the *singular foramen* for the posterior ampullary nerve and leads to the inferior cribriform macula.

THE ACOUSTIC NERVE.

The acoustic nerve (Figs. 671 and 672), whose relations at the base of the brain and whose origin in the brain have already (page 187) been described, enters the internal auditory pore, and in the internal meatus splits into its two terminal branches, the *cochlear* and the *vestibular nerves*. Both lie close together as far as the fundus of the internal auditory meatus, the former being medial and anterior to the latter. The vestibular nerve then forms a ganglion, the *vestibular ganglion*, from which its fibers (see page 187) arise and pass centrifugally, to their termination

FIG. 786.—The bony labyrinth seen from the inner side and in front. (Enlarged about seven times.)
The cochlea has been filed open from the side.

FIG. 787.—The bisected bony left cochlea. (Enlarged six times.)
* = Basal turn. ** = Middle turn. *** Apical turn.

FIG. 788.—The vestibular and cochlear fenestræ seen from the right tympanic cavity. (Enlarged about six times.)
* = Cavity of the pyramidal eminence. ** = Branches of the inferior tympanic vein.

FIG. 789.—The outer wall of the right vestibule. (Enlarged two times.)
The temporal bone has been sawn in a plane parallel with the axis of the pyramid. * = Basal turn of the cochlear canal.

FIG. 790.—The right vestibule exposed by the removal of its outer wall. (Enlarged three times.)

in the vestibular saccules and the semicircular canals, and centripetally to the nuclei on the floor of the rhomboidal fossa.

At the fundus of the internal auditory meatus the vestibular nerve divides into two branches, the *utriculo-ampullary* and *sacculo-ampullary* rami. The latter is the lower one, and again divides into two branches, the *saccular* and *posterior ampullary* nerves, the latter passing through the singular foramen to the inferior cribriform macula and ramifying in the ampullar crest of the posterior semicircular canal, while the saccular nerve passes through the inferior vestibular area to the middle cribriform macula of the vestibule and to the macula acustica of the saccule.

The stronger superior branch of the vestibular nerve, the *utriculo-ampullary ramus*, passes through the superior vestibular area and to the superior cribriform macula of the vestibule, and divides into the *utricular*, *superior ampullary* and *inferior ampullary nerves*, which end in the macula acustica of the utriculus and in the superior and lateral ampullar crests respectively.

The *cochlear nerve* enters the spiral foraminous tract in the cochlear area of the fundus of the internal auditory meatus, and through its foramina the bundles of the nerve pass in a spiral arrangement partly directly to the first portion of the basal convolution, partly first through the longitudinal canals of the modiolus. In the spiral canal they form the *spiral ganglion*, whose bipolar ganglion cells give origin to the cochlear fibers, these passing centripetally to the nuclei of the rhomboidal fossa, and centrifugally through fine canals in the osseous spiral lamina, extending from the tympanic lip to the spiral organ.

As regards the development of the labyrinth, the membranous labyrinth is first formed, then the bony one. The former arises from the external germ layer (see page 307) and at first appears as a groove-like invagination of the embryonic ectoderm called the auditory groove, which later forms a vesicle which is at first spherical and is known as the auditory vesicle or labyrinth vesicle. Of the various portions of the adult labyrinth the endolymphatic duct (sac) is the first to make its appearance, and by the appearance of constrictions in the walls of the vesicle a gradual separation into the sacculus and utriculus results. Before this is distinct the cochlear duct arises from what will later be the sacculus, appearing first as an almost straight evagination which only later, as it increases in length, begins to coil itself spirally. From the portion of the auditory vesicle which becomes the utriculus disc-like growths arise, which later form the semicircular canals, the borders of the disc widening, while the middle portion becomes thin and eventually breaks through.

The bony labyrinth arises from the cartilaginous investment of the auditory vesicle, that is to say, from the so-called cartilaginous ear capsule. This gives place to a bony capsule which is really the foundation of the petrous portion of the temporal bone (see Vol. I, page 58).

As regards the **blood-vessels** of the (membranous) labyrinth, all the arterial branches arise from the *internal auditory artery* (see page 37), which passes with the auditory nerve through the internal auditory meatus, but is distributed only partly in the labyrinth. The branches passing to the labyrinth are: 1. The *vestibular*. 2. The *common cochlear branch*. The former is the main artery for the vestibular saccules and the membranous semicircular canals, supplying the lateral

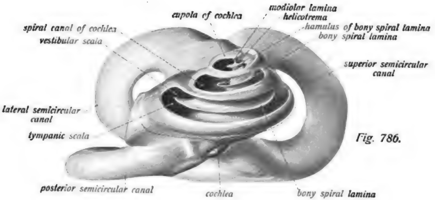

Fig. 786.

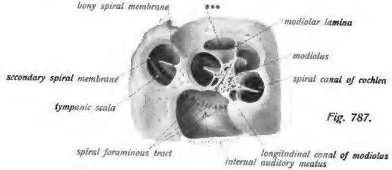

Fig. 787.

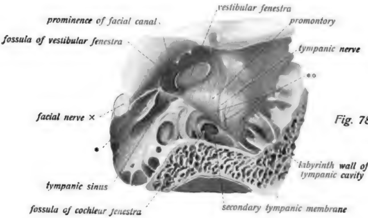

Fig. 788.

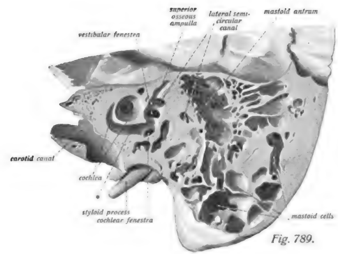

Fig. 789.

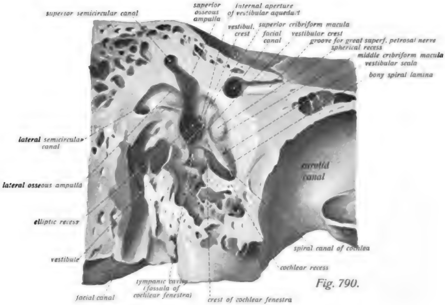

Fig. 790.

and superior walls of the saccules and the adjacent portions of the superior and lateral canal. The common cochlear branch divides into the *vestibulocochlear* and the *proper cochlear branches*; the former supplies the medial as well as the posterior wall of the two vestibular saccules, the posterior semicircular duct and the common limb of the other two, and also the first portion of the basal convolution of the cochlea; while the proper cochlear branch supplies the remainder of the cochlea, in which the blood-vessels, like the nerves, have a spiral course and form spiral glomeruli, known as the *arterial glomeruli of the cochlea*.

The veins of the labyrinth, in contrast to the arteries, flow off in three directions. The *internal auditory vein*, which accompanies the corresponding artery, receives only the veins from the main portion of the cochlea through the *spiral vein of the modiolus* which runs in the cochlear axis, while the *vein of the vestibular aqueduct* conducts the blood from the utriculus and the semicircular canals into the superior petrosal sinus. The third labyrinth vein is the *vein of the cochlear aqueduct*; it collects the blood of the sacculus and partly also that of the utriculus, and, furthermore, also the blood from the basal convolution of the cochlea and from the bony walls of the cochlea, and leads into the transverse sinus.

The labyrinth, like the eye, has no lymphatics. The perilymphatic spaces must be regarded as lymph-spaces; they communicate with the subarachnoideal space through the cochlear aqueduct.

The Middle Ear.

THE TYMPANIC CAVITY.

The *tympanic cavity* (Figs. 791 and 792) is a six-sided, air-containing cavity lying in the temporal bone, and is mainly formed by the petrous portion and tympanic portion of this bone. It is in direct communication on the one side with the external auditory meatus through the aperture intended for the tympanum (see below); on the other with the external base of the skull through the musculotubar canal. Furthermore, the mastoid antrum and the mastoid cells open into the tympanic cavity. The six walls of the tympanic cavity receive special names from the parts with which they are in relation. The superior wall, which is formed by the tegmen tympani of the temporal bone (see Vol. I, page 55), is called the *tegmental wall;* the medial wall, which touches the labyrinth, is the *labyrinth wall;* the inferior wall, the *jugular wall*, the jugular fossa lying on its inferior surface; the posterior wall, the *mastoid wall* (since it presents the entrance into the mastoid cells); the anterior wall, which is largely occupied by the mouth of the musculotubar canal, is the *carotid wall*, because of the proximity of the carotid canal; and the lateral wall is largely formed by the tympanic membrane, and is, therefore, called the *membranous wall* (in the macerated bone a large aperture represents the region occupied by the membrane).

Almost all the structures of the bony tympanic cavity are connected with the auditory organ, and are, therefore, described here.

The most important structures of the tympanic cavity are in the medial labyrinth wall. In about the middle of the wall is the *vestibular fenestra* (fenestra ovalis), which leads into the vestibule. It is kidney-shaped, superiorly convex and inferiorly concave, and has a transverse position. It does not quite stand on the general level of the labyrinth wall, but is at the bottom of a shallow, recess-like depression called the *fossa of the vestibular fenestra*. Just below it is a rounded elevation, the *promontory*, which is formed by the first portion of the basal convolution of the bony cochlea, and over the surface of the promontory a narrow groove runs vertically from above down, the *sulcus of the promontory*, due to the tympanic nerve (see page 207), which here passes over the medial wall of the tympanic cavity, accompanied by branches of the tympanic vessels (see below). Below and behind the promontory and almost completely concealed by it is a second, more rounded opening, the *cochlear fenestra* (fenestra rotunda), which leads into the

FIG. 791.—The right tympanic cavity opened by removing the outer and the contiguous portions of the anterior and superior walls. Seen from the outer side and in front. (Enlarged about two-thirds.)

FIG. 792.—The right tympanic cavity after the further removal of bone. (Enlarged about two-thirds.)
The carotid, facial, and musculotubar canals and the mastoid cells have been opened and the external auditory meatus completely removed. * = Opening of the cavity of the pyramidal eminence. ** = Cavity of the pyramidal eminence for the stapedius.

bony cochlear canal. It lies in a rather deep depression, the *fossa of the cochlear fenestra*, and has a rather definite border, the *crest of the cochlear fenestra.* The fossa is bounded posteriorly by a ledge-like bony ridge which starts from the vestibular fenestra and is known as the *subiculum of the promontory.* Above this is a small groove, the *tympanic sinus.* Close to the anterior surface of the vestibular fenestra the *cochleariform process* projects into the tympanic cavity as a curved, spoon-like, concave process; it is the free end of the septum of the musculotubar canal (see Vol. I, page 58).

The posterior wall of the tympanic cavity, the *mastoid* wall, is for the most part occupied by the communication with the air-containing cavities of the mastoid process of the temporal bone, the *mastoid cells*, the tympanic cavity leading especially into a large cavity, which is only indistinctly separated from it; this is the *mastoid antrum*, into which the separate mastoid cells open. In addition the posterior wall of the tympanic cavity, where it passes over into the medial wall, presents a distinct, elongated prominence above the vestibular fenestra; this is the *prominence of the facial canal*, and corresponds to the middle portion of the facial canal (see Vol. I, page 58). Above this prominence is a larger one, the *prominence of the lateral semicircular canal*, corresponding to the ampulla of this duct, and behind the vestibular fenestra and in front of the inferior portion of the prominence of the facial canal is a small cone-shaped process, which is hollow and is known as the *pyramidal eminence.* Its cavity opens into the tympanic cavity at the apex of the eminence, and a fine canal which leads from the facial canal into its cavity contains the nerve for the stapedius muscle (see below), which lies in the pyramidal eminence. Above the latter we usually find a small, but deep groove, called the *posterior sinus.* Furthermore, in the posterior wall of the tympanic cavity, above the posterior sinus, is a shallow groove, the *incudal fossa*, in which the short limb of the incus (see below) is fastened, and the *tympanic aperture of the canaliculus of the chorda tympani* (see Vol. I, page 57) occurs upon a small, transversely placed bony ridge situated just below the ring which serves for the attachment of the tympanic membrane and at the lower border of the posterior sinus.

The anterior wall of the tympanic cavity, the *carotid wall*, contains the opening of the musculotubar canal, and also the orifices of the small caroticotympanic canaliculi coming from the carotid canal.

The lateral wall of the tympanic cavity, the *membranous* wall, is mainly represented by a round aperture, closed, in the fresh condition, by the tympanic membrane, and above it is a small bony plate behind which lies the head of the malleus and partly the incus.

The superior or *tegmental wall* presents usually a very shallow evagination of the tympanic cavity, the *epitympanic recess*, which deepens to a hollow hemisphere toward the lateral wall, to form the *cupular portion.*

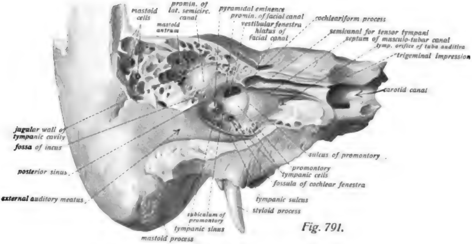

Fig. 791.

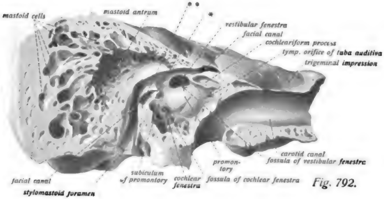

Fig. 792.

The inferior or ***jugular wall*** frequently shows the attachment of the styloid process to the temporal bone in the form of a low elevation, the ***styloid prominence.***

All the walls of the tympanic cavity, excepting the promontory and epitympanic recess, show groove-like depressions varying in size and form called *tympanic cells.* They extend as *tubar* (pneumatic) *cells* to the proximal portion of the tuba auditiva.

The space enclosed by the walls of the tympanic cavity has its smallest diameter from the medial to the lateral wall, since both the promontory and the tympanic membrane project into the lumen of the cavity; the least depth of the cavity in this diameter is 2.5 mm. The medial and lateral wall also approach one another below, and are more widely separated above. While the depth of the tympanic cavity is quite small, the height is rather considerable, reaching in the region of the epitympanic recess a maximum of 15 mm.; the longitudinal diameter of the cavity is about 13 mm. The measurements, however, vary individually to a very high degree. The walls of the tympanic cavity are not separated from one another by sharp angles, but pass, in part, into one another in an arched manner, this being the case in the passage of the anterior into the inferior wall, the superior into the lateral, and the posterior into the inferior.

THE AUDITORY OSSICLES.

The three ***auditory ossicles*** (Figs. 793 to 799), the smallest bones of the body, lie in the tympanic cavity in such a way that the largest, the ***malleus***, is in contact and fused with the tympanic membrane, the middle one, both as to its size and position, the ***incus***, unites the former with the smallest one, the ***stapes***, which lies against the vestibular fenestra. The three ossicles, therefore, form a chain extending between the lateral and medial walls of the tympanic cavity.

The ***malleus*** has rather the shape of a club than that of a hammer. It possesses a rounded ***head*** or ***capitulum***, a constriction below the head, the ***neck*** (***collum***), a ***manubrium***, and also two processes. The head is the largest part of the ossicle and is rounded off at its superior end, while its posterior surface is provided with a saddle-shaped, transverse, cartilaginous articular surface for the incus. The rounded-off portion of the head lies in the epitympanic recess, close beneath the tegmen tympani. Below the articular surface of the head there is a strong constriction known as the ***neck*** or ***collum***, which, like the head, also lies above the tympanic membrane, behind the thin plate of bone which here separates the tympanic cavity from the external auditory canal. As a prolongation of the neck comes the ***manubrium;*** it is an elongated, round rod of bone which decreases slightly in size from above downward, is flattened a little at the apex, and is fastened throughout its entire length to the tympanic membrane, its broadened apex corresponding to the umbo of the tympanic membrane. The manubrium does not lie exactly in the line of the head and neck, but forms an angle of 125° to 150° with them, so that the head and neck project further into the tympanic cavity than the manubrium. Of the two processes of the malleus, the ***lateral process*** arises from the base of the manubrium as a short, thick process which projects laterally toward the tympanic membrane and produces upon it the malleolar prominence (see below). The ***anterior process*** (processus Folianus gracilis) is a long slender rod of bone, which is usually longer in the new-born than in the adult. It arises on the anterior surface of the manubrium, and thence, lying in the anterior ligament of the malleus (see below) and gradually passing over into it, passes forward and down, toward the petrotympanic fissure.

FIG. 793.—The right malleus from the outer side. (Enlarged seven times.)
FIG. 794.—The right malleus from in front. (Enlarged seven times.)
FIG. 795.—The right malleus from behind. (Enlarged seven times.)
FIG. 796.—The right incus from the outer side. (Enlarged seven times.)
FIG. 797.—The right incus from the inner side. (Enlarged seven times.)
FIG. 798.—The right stapes from above. (Enlarged seven times.)
FIG. 799.—The right stapes from the inner side and from below. (Enlarged seven times.)
FIG. 800.—The right auditory ossicles of a child. (Enlarged seven times.)
* = Articular projection. ** = Site of insertion of tensor tympani. + = Site of insertion of stapedius.

The *incus* has almost the shape of a double-rooted molar tooth with unequally long roots. It possesses a body and two processes which are broad at the base and terminate in a point below. The *body* faces forward and has upon its upper surface a saddle-like depression which is covered by cartilage, for the reception of the head of the malleus. The *long limb* of the incus lies exactly parallel to the manubrium of the malleus, but a little medial and posterior to it. It is, however, shorter than the manubrium, and at its end it bears a small disc-shaped expansion, the *lenticular process*. The short crus faces the tympanic antrum and is almost horizontal; with its blunted tip it rests in the incudal fossa of the tympanic cavity.

The *stapes* corresponds in shape almost completely to its name (stirrup). It presents a flat, oval *base* which fits into the vestibular fenestra, and has, therefore, an upper convex and an inferior concave border. In addition the bone possesses two limbs and a head. The *limbs* arise from the two ends of the base and pass almost horizontally lateralward. The *anterior limb* is somewhat the shorter and less curved and the *posterior* one more strongly curved, the latter also having a roughened area for the insertion of the tendon of the stapedius muscle just before its attachment to the capitulum. The two limbs unite at the *head* of the stapes, which bears a small articular surface for the lenticular process of the long limb of the incus.

The three ossicles are connected with one another by two joints, the *articulations of the auditory ossicles*. The union of the manubrium and incus is the *incudomalleolar articulation*, and is a saddle-shaped joint. The head of the malleus has a prominently convex, the body of the incus a concave, articular surface, both being covered with cartilage and enclosed by a delicate capsule. The articular surfaces of the two bones each possess, in addition, a spur-like process on the inferior surface, and frequently the joint possesses an articular disc. The articulation between incus and stapes, the *incudostapedial articulation*, is between the lenticular process of the incus and head of the stapes. It is an ellipsoid articulation resembling very much a ball-and-socket joint, and has a very thin capsule. The plane of the stapes, which connects both limbs, is almost perpendicular to the long axis of the long limb of the incus.

In addition to these articulations there are also a number of ligaments which hold the ossicles in place, and also the *tympanostapedial syndesmosis*, which is the connection of the base of the stapes with the vestibular fenestra. The opening of the latter is closed by the periosteum of the vestibule, and the narrow space which remains between its bony border and the base of the stapes is filled by connective tissue, called the *basal ligament* of the stapes.

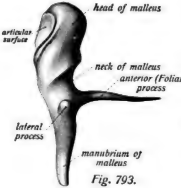

Fig. 793.

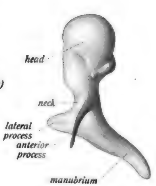

Fig. 794.

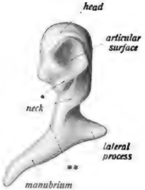

Fig. 795.

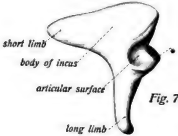

Fig. 796.

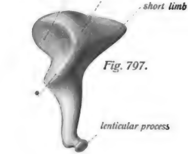

Fig. 797.

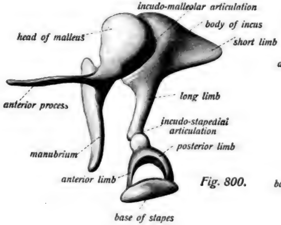

Fig. 800.

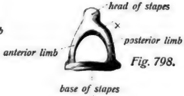

Fig. 798.

Fig. 799.

THE LIGAMENTS AND MUSCLES OF THE AUDITORY OSSICLES.

Three ligaments serve for the fixation of the malleus (Figs. 801 and 802). The *superior ligament* fastens the head of the malleus, in the epitympanic recess, to the inferior surface of the tegmental wall, and is usually very short. The *lateral ligament* arises from the border of the tympanic membrane in the region of the tympanic notch and passes toward the neck of the malleus, where it is inserted at the base of the two processes of the malleus. The *anterior ligament* surrounds the anterior (Folian) process, passing directly over into it and appearing to be a direct continuation of it. It passes to the petrotympanic fissure and traverses it, to be attached to the angular spine of the sphenoid (petrotympanic ligament). A stronger, more independent bundle of fibers passes, united with the preceding ligament, between the neck of the malleus and the posterior tympanic spine. In addition the manubrium is fastened to the tympanic membrane (see below).

The incus is held in place by the following ligaments (Figs. 801 to 803): The *superior ligament* passes in front of the body of the incus to the roof of the tympanic cavity; the *posterior ligament* is a short, tense band, fastening the long limb in the incudal fossa of the tympanic cavity (see page 286).

The *obturator membrane of the stapes* (Fig. 804) is a very delicate membrane which occupies the interval between the limbs of the stapes.

For the movement of the auditory ossicles there are two small muscles, the larger of which is inserted into the malleus, the smaller into the stapes. The *tensor tympani* (Figs. 801, 802, and 804 to 806) is a rather long muscle occupying the upper portion of the musculotubar canal, which is known as the *semicanal of the tensor tympani muscle.* It arises from the walls of the canal and also from the cartilage of the tuba auditiva and from the neighborhood of the spheno-petrosal fissure, and courses through its semicanal, completely shut off from the tuba auditiva as far as its tympanic end by a strong layer of periosteum, and at the root of the cochleariform process it passes over into a slender, round tendon, which, passing through the spoon-like concavity of the process, is bent almost at a right angle and then passes almost transversely (from within outward) across the tympanic cavity to the malleus. Its insertion is at the medial side of the base of the manubrium of the malleus, opposite the lateral process.

The *stapedius* (Figs. 804 and 805) is smaller than the tensor tympani and is the smallest muscle in the body. It has an elongated, pyriform shape and is completely inclosed in the cavity of the pyramidal eminence, from whose walls it arises, and is inserted by a short, thin tendon close to the capitulum. After its exit from the cavity of the pyramidal eminence the tendon bends somewhat downward.

The auditory ossicles develop from various structures. The stapes arises from the (pre-) cartilaginous labyrinth* (see page 284), while the malleus and incus have their origin from the first visceral arch (see page 308).

While the function of the stapedius is still unknown, the tensor tympani, as its name implies, serves to tense the tympanic membrane by drawing the malleus and tympanic membrane inward toward the tympanic cavity. The stapedius is innervated by the facial nerve, which passes immediately beside it, while the tensor tympani is supplied from the otic ganglion.

*[It has also been maintained that the stapes is formed from the upper end of the second visceral arch cartilage.—Ed.]

FIG. 801.—The right tympanic cavity opened from above. (Enlarged five times.)

The tegmen tympani, the upper wall of the musculotubar canal, and the roof of the mastoid antrum have been removed; a small portion of the facial nerve has been exposed in the vicinity of the geniculum. * Folds of mucous membrane of the mastoid antrum.

FIG. 802.—The outer wall of the right tympanic cavity as seen from the inner side. (Enlarged five times.)

The malleus, the incus, the tensor tympani, the membrana tympani, and the tube are shown in their reciprocal relations, since the inner wall has been removed by a section approximately parallel to the membrana tympani. The greater portion of the tensor tympani has been exposed by the removal of the periosteum. The stapes has been removed with the inner wall of the tympanum.

FIG. 803.—The outer wall of the right tympanic cavity seen from the inner side. (Enlarged five times.)

General preparation as in Fig. 802. In addition the chorda tympani and the tympanic aperture of the canaliculus of the chorda tympani have been exposed, the tensor tympani with the greater portion of the musculotubar canal removed, and the tendon of the tensor cut off close to the malleus. * — Fold of mucous membrane.

FIG. 804.—The inner wall of the right tympanic cavity seen from the outer side. (Enlarged five times.)

Preparation as in Fig. 801. In addition the upper and the outer walls of the cavity and the greater portion of the external auditory meatus have been removed. A small portion of the tympanic membrane has been retained.

FIG. 805.—The inner wall of the right tympanic cavity seen from the outer side. (Enlarged five times.)

Preparation as in Fig. 804. In addition the posterior wall has been partly removed, the stapedius exposed, the lower portion of the facial canal opened or removed, and the external semicircular canal opened up.

FIG. 806.—A frontal section of the right external auditory meatus, of the tympanic membrane, and of the tympanic cavity. (Enlarged four times.)

* = Apical recess of tympanic cavity.

THE TUBA AUDITIVA OR EUSTACHIAN TUBE.

The tuba auditiva or Eustachian tube (Figs. 801 to 805 and 809 to 811) is a long, almost straight, flattened canal which connects the tympanic cavity with the nasopharyngeal cavity. Since the tympanic membrane (see below) is air-tight, the Eustachian tube is the only way by which the air of the middle ear stands in communication with that of the outside.

The tuba auditiva is divisible into two parts, an *osseous portion* lying in the semicanal and a *cartilaginous portion.* The osseous portion begins at the carotid wall of the tympanic cavity as an irregularly shaped, not very sharply defined opening, the *tympanic aperture* (*ostium*), and follows exactly the course and shape of the osseous (semi-) canal, being separated from the tensor tympani partly by the bony septum of the musculotubar canal, partly by the periosteal covering of the muscle mentioned above. In the lower wall, near the tympanic opening, there are inconstant *tubar pneumatic cells,* described above (page 287). The cartilaginous portion opens as the pharyngeal aperture into the nasopharyngeal cavity (see Vol. II, page 41). Its transition into the osseous portion takes place in the region of the sphenopetrosal fissure at the medial opening of the musculotubar canal, the cartilage being attached directly to the margin of the bony semicanal.

The *cartilage of the tuba auditiva,* which serves as a support for the tube, occurs only in its superior and medial walls. Its shape is that of a plate, bent so as to enclose a very narrow groove (Fig. 811), the two lamellæ enclosing the groove being known as the *lateral* and *medial cartilaginous laminæ.* They are continuous by their upper borders, so that the groove opens downward. The medial lamina in the region where the tuba reaches its greatest diameter, namely toward the pharyngeal opening, is higher and considerably thicker than the lateral, which, as a hook-shaped plate,

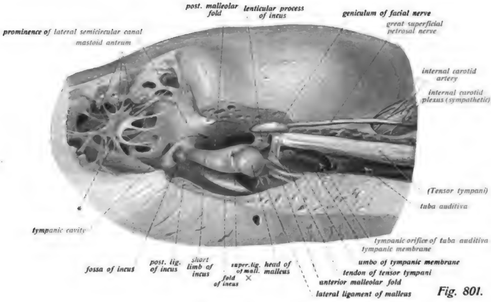

Fig. 801.

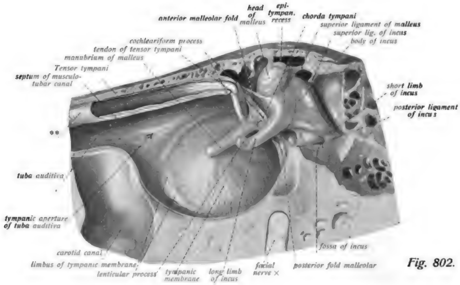

Fig. 802.

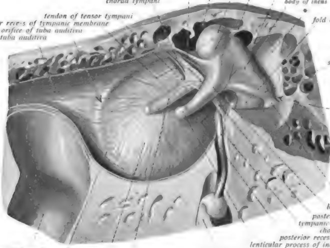

Fig. 803.

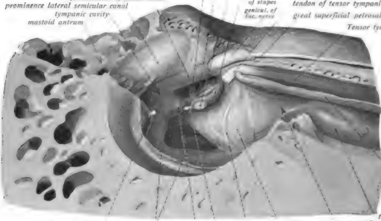

Fig. 804.

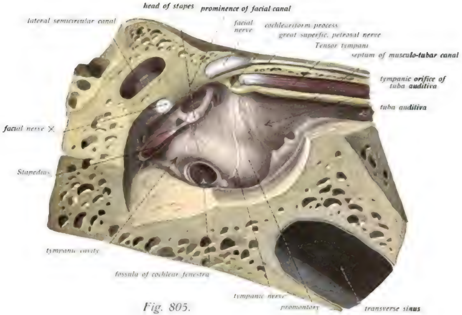

Fig. 805.

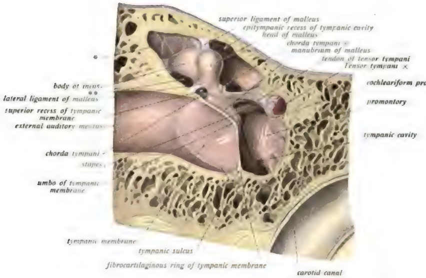

Fig. 806.

is in relation only with the superior portion of the lateral wall of the tuba, while the lower part of the lateral wall and the inferior wall are formed by a connective-tissue membrane, the *membranous lamina*, which extends between the free edges of the cartilaginous laminæ. The medial and lateral cartilage lamellæ lie very close together, so that the space between them is very narrow, and the lumen of the cartilaginous part of the tuba is, therefore, a vertical slit. The cartilage, where it begins at the end of the osseous portion, is low and narrow, and almost completely surrounds the lumen of the tuba ring, but it becomes considerably thicker and higher toward the opening into the pharynx, the medial lamella, which is especially thick, here causing the projection known as the torus tubarius (see Vol. II, page 41).

The cartilage of the tuba auditiva rests upon the fiber mass which closes the sphenopetrosal fissure and in the sulcus of the tuba auditiva of the sphenoid bone, although the portion at the pharyngeal opening projects freely beyond the bone. Structures having an intimate relation to the wall of the tube are the levator and especially the tensor veli palatini, whose origins are to a large extent from the cartilaginous portion of the tube, the latter, especially, acting on the tube and dilating its lumen.

The inner surface of the whole length of the Eustachian tube, in the osseous as well as in the cartilaginous portion, is lined by a mucous membrane which is a prolongation of the mucous lining of the tympanic cavity. It forms longitudinal folds and contains *mucous glands* and *lymph nodules*. In the osseous portion the lumen is triangularly prismatic, in the cartialginous portion slit-like (see above), and its narrowest point is at the transition of the cartilaginous into the osseous portion, and is designated as the *isthmus*. Here the otherwise almost straight tuba has a very slight bend, on either side of which its lumen widens toward either opening, although in the cartilaginous portion it is probably kept open only by the muscle fibers of the tensor veli palatini. Its greatest width is just in front of the pharyngeal aperture.

The two tubæ auditivæ converge toward their pharyngeal openings, the direction of each being from above, behind and laterally, downward, anteriorly, and medially, describing an angle of about 30° to 40°* with the horizontal plane, and about 45° with the median plane. The downward inclination actually occurs only in the cartilaginous portion, the osseous portion lying on the whole, in the direct continuation of the axis of the tympanic cavity. The length of the whole tube is about 33 to 35 mm., the height of the lumen at the pharyngeal opening 9 mm., and the width 5 mm., while at the tympanic opening the similar measurements are 5 and 3 mm.

THE TYMPANIC MEMBRANE AND THE MUCOUS TUNIC OF THE TYMPANUM.

The *tympanic membrane* (Figs. 801 to 808, 812, and 813) is a very thin (about 1. 1 mm.), and tightly stretched membrane, which closes the tympanic cavity laterally, and thus forms the boundary between the middle and the external ear. It is almost circular and measures about 8 to 9 mm. in diameter, but is usually a little higher (up to 10 mm.) than broad, and is thus really a short ellipse. In the new-born child it is attached to the tympanic annulus of the temporal bone, which forms about three-fourths of a circle, and in the adult a fine groove, the *tympanic sulcus*, serves for its attachment. In the upper fourth the boundary of the tympanic membrane is lacking, so far as the tympanic portion of the temporal bone is concerned, and here the squamous

* The size of the angle varies individually according to the general form of the skull.

FIG. 807.—The outer wall of the right tympanic cavity as seen from the outer side. (Enlarged five times.)

The tympanic membrane has been removed together with the wall of the external auditory meatus. * Layer of periosteum which conceals the tensor tympani.

FIG. 808.—The right tympanic membrane as seen from the inner side.

The contents of the tympanic cavity and the tympanic mucous membrane have been almost entirely removed, but the manubrium of the malleus has been left behind.

FIG. 809.—The cartilage of the tuba auditiva and its relations to the base of the skull.

FIG. 810.—A cross-section of the cartilaginous portion of the left tuba auditiva near its junction with the osseous portion. (Enlarged two times.)

FIG. 811.—A cross-section of the cartilaginous portion of the left tuba auditiva near its pharyngeal orifice. (Enlarged two times.)

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portion of the temporal bone forms the arch-like boundary of the *tympanic notch*, extending between the tympanic spines (major and minor) of the tympanic portion. In the region of the tympanic notch the tympanic sulcus is absent. The tympanic membrane is attached at the sulcus by a circular thickening, the *fibrocartilaginous ring*, which forms the periphery of the tympanic membrane, the *limbus of the tympanic membrane.*

In the tympanic membrane two portions, differing decidedly in character, can be distinguished, a *tense portion* and a looser superior or *flaccid portion* (Shrapnell's membrane), the latter corresponding to the tympanic notch. The tense portion is drawn in like a funnel by the manubrium of the malleus, which is fastened to it, and the depression which is thus formed upon the surface of the membrane which faces the external auditory canal is called the *umbo.*

The tympanic membrane consists of three layers: first, of a middle *lamina propria* composed of connective tissue, and second, of the epithelium of the two surfaces. The medial surface of the tympanic membrane, facing the tympanic cavity, has an epithelium continuous with the very thin mucous membrane of the tympanic cavity and is known as the *mucous layer of the tympanic membrane*, while that of the lateral surface, facing the external auditory meatus, is continuous with epithelium lining the meatus (see page 295), and is the relatively thicker *cutaneous layer of the tympanic membrane.* The lamina propria in the region of the tense portion of the membrane consists of radial fibers on the lateral surface (*stratum radiatum*) and circular fibers on the medial surface (*stratum circulare*), but both layers (that is, the whole lamina propria) are absent in the flaccid portion, so that here the tympanic membrane consists only of the cutaneous and mucous layers, and since it is the lamina propria which gives tenseness to the tympanic membrane, the flaccid portion is loose.

The lateral surface of the tympanic membrane (Fig. 812) has a shining appearance and shows light reflections. The whole length of the manubrium of the malleus, from the umbo up, shines through the membrane as a bright strip, the *malleolar stria*, and since the apex of the manubrium extends below the middle of the tympanic membrane, the umbo of the latter has an eccentric position. At the superior end of the malleolar stria is a small prominence which corresponds to the superior border of the tense portion and is produced by the lateral process of the malleus; it is known as the *malleolar prominence.* The flaccid portion begins above this prominence, and otherwise the tympanic membrane seems smooth and free from folds on the lateral surface. This is not the case, however, on the medial surface, which faces the tympanic cavity.

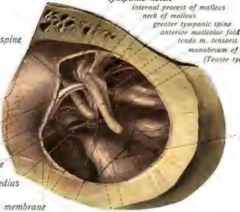

Fig. 807.

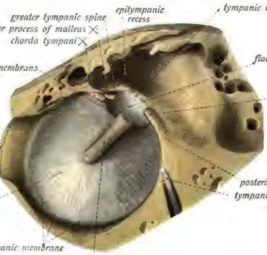

Fig. 808.

Fig. 809.

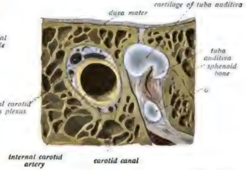

Fig. 810.

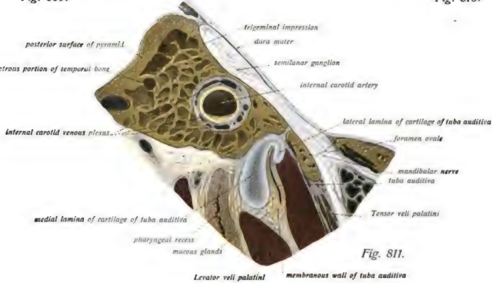

Fig. 811.

In the first place the manubrium is not fastened to the membrane in such a way that the mucosa of the tympanic cavity covers both structures independently, but the bone is partly actually imbedded into the substance of the tympanic membrane (lamina propria). Furthermore, the mucous membrane forms curved folds, the *membranous folds of the tympanum*, which start at the malleolar prominence and mark the boundary between the tense and flaccid portions of the membrane. There is a shorter *anterior membranous fold*, passing to the minor tympanic spine, and a longer *posterior membranous fold*, passing to the major spine.

The tympanic membrane is placed obliquely to the axis of the external auditory canal (see page 295) in a double sense. In the first place the anterior border of the membrane is somewhat medially and the posterior one lateral, so that the anterior wall of the auditory meatus is considerably longer than the posterior. And, secondly, the upper border of the membrane is a little further forward than the lower one. Consequently, the membrane stands obliquely in the vertical as well as in the horizontal plane, and it is also funnel-shaped on account of the depression at the umbo. The upper and lower halves of the funnel form different angles with the wall of the auditory meatus, the upper forming an obtuse (about 140°) and the lower an acute (about 27°) angle.

The tympanic cavity throughout its whole extent is covered by a very thin and delicate *mucosa*, which extends also into the antrum and the mastoid cells, and is connected with the pharyngeal mucosa through the tuba auditiva. This mucosa forms a larger number of folds, some of which are extremely delicate in form. Beside numerous variable folds, there are two rather constant ones in the vicinity of the tympanic membrane and of the malleus; these are two strong, semicircular folds called the malleolar folds. The *anterior malleolar fold* (Fig. 803) contains the chorda tympani, the anterior malleolar ligament, and the anterior malleolar process, and, arising from the major tympanic spine, is inserted on the neck of the malleus. The larger *posterior malleolar fold* contains in its narrow border the chorda tympani as it emerges from the tympanic aperture of the chorda tympani canal, and passes from the minor tympanic spine to the neck of the malleus. It is situated very close to the tympanic membrane and is partly connected with its mucous layer.

Usually there are also mucous folds in connection with the incus and stapes. The *incudal fold* passes from the long limb to the posterior wall of the tympanic cavity; the *stapedial fold* covers the tendon of the stapedius, the stapes, and the obturator membrane of the stapes. Smaller folds cover the membrane which closes the cochlear fenestra, the *secondary tympanic membrane;* the tendon of the tensor tympani also runs in a mucous fold and, finally, folds are also usually found in the epitympanic recess (see below).

A number of blind pockets are formed partly by the folds just mentioned, partly by projections of the bony walls of the tympanic cavity. The slit-like spaces, opening below, which are formed by the malleolar folds and lie between these and the tympanic membrane are known as the *anterior* and *posterior recesses of the tympanic membrane.*

The *superior recess of the tympanic membrane* (Prussak's space) (Fig. 806) is a narrow space which lies between the flaccid portion of the tympanic membrane and the neck of the malleus. It is bounded inferiorly by the lateral malleolar process, superiorly by the lateral malleolar ligament, and it communicates with the posterior recess of the tympanic membrane.

FIG. 812.—The right tympanic membrane as seen from the outer side. (Enlarged five times.)

The greater portion of the wall of the external auditory meatus has been removed. * Cut surface of the bone ** Cross-section of the mucous membrane of the external auditory meatus.

FIG. 813.—A frontal section of the external auditory meatus, of the tympanic cavity, and of the labyrinth. (Enlarged two times.)

: = Apical recess of the tympanic cavity. + + Oblique section of the wall of the external auditory meatus.

The *epitympanic recess* (attic) (Figs. 802, 803, 806 and 808) is the portion of the tympanic cavity above the tympanic membrane which contains the head of the malleus and the body of the incus. It is bounded laterally by the lateral wall of the tympanic cavity and by the cupular portion of the tegmen tympani, and is partly separated from the superior recess of the tympanic membrane by the lateral malleolar ligament. It contains folds of the mucous membrane. The epitympanic recess, the superior and the anterior and posterior recesses of the tympanic membrane, lie in order, one below the other.

THE VESSELS AND NERVES OF THE TYMPANIC CAVITY.

It is characteristic of the blood-supply of the tympanic cavity that the arterial branches come from several, sometimes rather distant, sources. There are four different tympanic arteries, which enter the tympanic cavity in different ways. The largest is the *anterior tympanic* from the internal maxillary (see page 27), and enters the tympanic cavity in company with the chorda tympani through the petrotympanic fissure; the *posterior tympanic* is a small branch of the stylomastoid (from the posterior auricular, see page 26) and passes through the canaliculus of the chorda tympani; the *inferior tympanic* comes from the ascending pharyngeal (see page 24) and passes through the tympanic canaliculus; the *superior tympanic* arises from the middle meningeal (see page 28) and passes through the superior aperture of the tympanic canaliculus. In addition, a *caroticotympanic branch* passes from the internal carotid (see page 31) to the tympanic cavity. A branch of the inferior tympanic passes with the tympanic nerve over the promontory, and the medial side of the tympanic membrane is also supplied by the arteries of the tympanic cavity. The veins follow the arteries in their course. The lymph-vessels are still but little known.

The nerve of the tympanic cavity (including the mucous layer of the tympanic membrane) is the tympanic nerve, which courses over the promontory (see page 207), and, together with the sympathetic branches of the plexus of the internal carotid artery (caroticotympanic nerves), forms the tympanic plexus (see page 207). The chorda tympani traverses the tympanic cavity without giving off any branches, and the facial nerve, also, except for the innervation of the stapedius, has no distribution to the tympanic cavity.

As regards the development of the middle ear, the tympanic cavity, as well as the tuba auditiva, is formed from the first pharyngeal pouch, just as the external auditory meatus (see below) develops from the remains of the first branchial cleft (see also page 308). The tympanic membrane is from the thin lamella which separates the first pharyngeal pouch from the first branchial cleft.

THE EXTERNAL EAR.

The external ear consists of the *external auditory meatus* and the *auricle*. The tympanic membrane separates it from the middle ear.

THE EXTERNAL AUDITORY MEATUS.

The *external auditory meatus* (Figs. 806 and 813) is divisible into two portions. The medial part is enclosed by bone, and is known as the *osseous external auditory meatus*, while the lateral part is enclosed by cartilage, and is known as the *cartilaginous external auditory meatus*. The two parts pass into one another at the external auditory pore, the osseous portion, therefore, extending from the pore to the groove in the tympanic portion of the temporal bone, in which the tympanic membrane is attached. Since this membrane is very obliquely inclined to the axis of

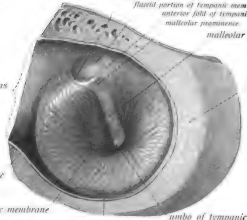

Fig. 812.

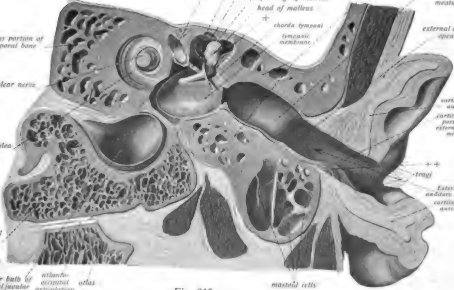

Fig. 813.

the external auditory canal, the upper wall of this is 6 to 7 mm. shorter than the lower, and the posterior about 5 mm. shorter than the anterior. The cartilage of the cartilaginous portion of the external auditory meatus is a part of the cartilaginous skeleton of the external ear and is firmly attached to the external auditory pore by connective tissue. The entrance into the cartilaginous portion is in the auricle behind the tragus (see below).

The external auditory meatus is almost in the frontal plane and horizontal, and, therefore, its course from the auricle to the tympanic membrane almost exactly from without medially, the deviation from the horizontal direction being but small, that from the frontal plane a little larger, the axes of the two meatuses converging anteriorly. Furthermore, the course of the auditory meatus is not straight, but presents certain somewhat variable curvatures, mainly in the cartilaginous portion. One bend occurs immediately medial to the entrance and is convex superiorly and anteriorly, and a second one, somewhat less distinct than the first, is in the neighborhood of the boundary between the cartilaginous and bony portions, and is convex posteriorly and inferiorly. Beyond, the osseous portion is again directed a little forward.

The length of the external auditory meatus differs considerably in different individuals, and the length of its roof also differs from that of its floor (see below); on the average it is about 35 mm. long, and of this distance about one-third (14 mm.) belongs to the osseous portion and two-thirds (21 mm.) to the cartilaginous portion. The shape, and especially the width, of the lumen also vary greatly. A cross-section of it is usually irregularly elliptic, but it narrows from the entrance to the end of the cartilaginous portion and then widens again in the osseous part, and, finally, narrows down once more. The inferior wall of the meatus forms an acute angle with the tympanic membrane (see page 293).

The lumen of the external auditory canal is lined by a prolongation of the integument of the auricle, which, greatly attenuated, forms also the cutaneous layer of the tympanic membrane. In the region of the osseous portion this integument is thin and tightly adherent to the periosteum, but it is considerably thicker in the cartilaginous portion, and, besides sebaceous glands and fine hairs, possesses special ceruminous glands which are to be regarded as modified sudoriparous glands.

As regards the relations of the external auditory meatus it may be stated that it lies in the immediate vicinity of the temporomandibular articulation, being located just behind it; and, furthermore, the inferior and anterior walls of the cartilaginous portion are surrounded by the lobules of the parotid gland.

The blood-vessels of the cartilaginous portion of the external auditory meatus are branches of the same vessels which supply the auricle—namely, the anterior auricular branches of the superficial temporal (see page 26) and the auricular branches of the posterior auricular. The osseous portion is supplied mainly by the deep auricular branch of the internal maxillary artery. The veins correspond to the arteries. The lymph-vessels flow partly to the parotid lymph-nodes and partly to the deep cervical nodes. The nerves are—first, branches of the auriculotemporal nerve (see page 203), which supply the anterior surface; and, secondly, the posterior surface is innervated by the auricular branches of the vagus.

As regards the development of the external auditory meatus it is the sole remaining portion of the first branchial groove of the embryo (see page 308) and represents its dorsal part. By the sixth week of embryonic life all other clefts have already closed, and the ventral end of the first one also, its dorsal end, however, persisting to form the external auditory meatus (see page 293). The bony portion of the meatus is entirely absent in the newborn child, because of the flat form of the tympanic part of the petrosal bone; it develops only gradually as this part of the temporal bone assumes its trough-like form (see Vol. I, page 59).

FIG. 814.—The right external ear as seen from the outer side.

FIG. 815.—The cartilage of the right external ear as seen from in front.

The cartilage is represented in its natural connection with the temporal bone. The anterior portion of the squama temporalis has been sawn away.

FIG. 816.—The cartilage of the right external ear as seen from the outer side.

FIG. 817.—The cartilage of the right external ear as seen from the inner side.

FIG. 818.—The right external ear separated from the head and viewed from the inner aspect.

* = Cut margin of integument.

FIG. 819.—The muscles of the inner aspect of the auricle.

FIG. 820.—The muscles of the outer aspect of the auricle.

THE AURICLE.

The *auricle* (pinna) (Figs. 814 to 820) is an elongated, almost shell-like structure, fastened at an acute angle on the lateral surface of the head, its rather concave surface being directed laterally and forward, while the convex surface looks for the most part medially and backward.

The frame-work of the auricle is a very complex plate of elastic cartilage termed the *cartilage of the auricle*, the majority of whose folds can be easily recognized through the skin without further preparation. The sharply bent border which surrounds the superior, posterior, and upper parts of the anterior surface of the auricle is called the *helix*,* its anterior portion, which lies almost horizontally above the external auditory meatus, being the crus of the helix, and the anteriorly directed spine occurring on this, the *spine of the helix*. Posteriorly and inferiorly the helix terminates a free, flattened process, the *cauda*. Parallel to the helix is the *anthelix*, which arises below the highest point of the curvature of the helix by two limbs, the *crura of the anthelix*, between which is a deep depression, the *triangular fossa*, while between the helix and anthelix there is an elongated, deep groove or furrow termed the *scapha*.

The large depression between the anthelix and the anterior portion of the helix is the *concha*, and is really the floor of the auricle. From it the crus of the helix has its origin and divides the groove of the concha into the *cymba of the concha*, lying between the crus of the helix and anthelix, and the real vestibule of the external auditory meatus, the *cavity of the concha*. The lower anterior part of the cartilage is formed by the *lamina of the tragus* and the cartilage of the external auditory meatus. The former, covered by its integument (see below), forms the *tragus* † at the anterior entrance of the external auditory meatus, and is continued medially without any demarcation, into the cartilage of the auditory meatus.

Opposite to the lamina tragica the auricular cartilage is slightly curved upon itself, forming the *antitragus*, which is separated from the cauda of the helix by a deep fissure, the *antitrago-helicine fissure*, and from the lamina tragica by a rounded groove, the *intertragic notch*. This notch corresponds to the narrow connecting bridge called the *isthmus*, which connects the cartilage of the external auditory meatus and the lamina tragica on the one side with the main portion of the auricular cartilage on the other, these two main portions of the cartilage being separated medially by a deep slit, the *terminal notch of the auricle*.

Corresponding to the depressions of the lateral surface of the auricle there are prominences

* At the upper end of the helix there is frequently a small projection, the *auricular tubercle* (Darwin's tubercle), and a little behind its upper end the helix is often drawn out to a point, the *auricular apex* (Darwin's apex).

† Above the tragus there is often a small projection, the *supratragic tubercle*.

Fig. 814.

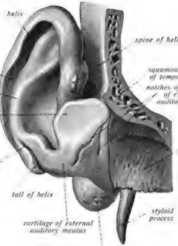

Fig. 815.

Fig. 816.

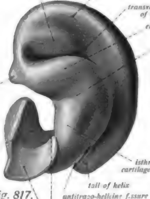

Fig. 817.

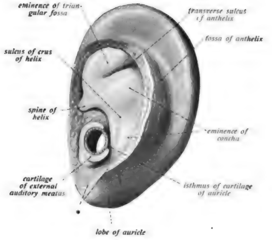

Fig. 818.

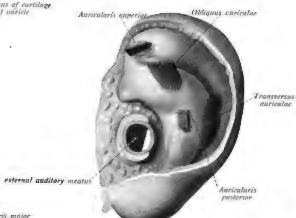

Fig. 819.

Fig. 820.

on the medial surface: the *eminence of the triangular fossa, of the concha*, and *of the scapha.* The first two are separated by the *transverse sulcus of the anthelix*, a groove which corresponds to the crus of the anthelix and passes over into the corresponding fossa of the anthelix, lying between the three eminences. The medial surface of the auricle also shows a transverse fissure, the *sulcus of the helix*, which represents the corresponding elevation of the lateral surface.

The *cartilage of the external auditory meatus* begins laterally as the *lamina of the tragus*, and is a groove-like semicanal which is interrupted by (usually two) vertical incisions, the *notches of the cartilaginous external auditory meatus* (notches of Santorini); the noncartilaginous portion of the wall (the posterior superior surface) is filled in by connective tissue, just as are the incisures.

The external integument covers the cartilage of the auricle in such a way, that almost all its elevations are plainly visible, a condition due to the fact that the skin of the external ear is almost free of fat, and, therefore, fits itself exactly to the folds of the auricle. A departure from this condition is found only at the following places; first, the *auricular lobe* contains no cartilage, but is a duplication of skin filled with an accumulation of fat; second, in the antitragicohelicine fissure and the portion of the terminal auricular fissure, which lies between the crus of the helix and the lamina of the tragus, the cartilage is lacking. Over the terminal fissure there is a simple groove, the *anterior auricular notch*, along which the skin of the auricle cartilage becomes continuous with that of the cheek, and over the antitragohelicine fissure there is a shallow furrow, the *posterior auricular sulcus.* While the lateral surface of the auricular cartilage is completely covered by integument, only the superior and posterior portions of the medial surface are so covered, the integument being reflected to the temporal and mastoid regions of the cranium without actually covering the medial surface of the concha.

In addition to the three portions of the auricularis muscle which serve to move the ear (see Vol. I, page 179) there are some other very small muscles which are no longer functional and are sometimes partly replaced by connective tissue. The *helicis major* is an elongated, flat muscle which passes from the spine of the helix to the superior border of the bend of the anterior crus of the helix. The *helicis minor* lies upon the crus of the helix; it is shorter than the preceding, and passes obliquely from in front and above, downward and backward. The *tragicus* is broadly rectangular, arising from the lamina of the tragus and passing upward. The *antitragicus* lies in the antitragus, behind the intertragic notch, and connects the antitragus and the anthelix. The *transversus auriculæ* consists of short fibers often separated by interspaces, and lies on the posterior surface of the auricle, where it connects the eminence of the concha with that of the scapha. The *obliquus auriculæ* is a small, weak bundle which connects the eminence of the triangular fossa and the eminence of the concha.

The blood-vessels of the auricle are, for the anterior part, branches of the *superficial temporal artery* (*anterior auricular arteries*) and for the posterior part branches of the *posterior auricular artery.* The veins correspond with the arteries. The lymph-vessels pass partly forward into the parotid lymph-nodes in the vicinity of the ear, and partly backward into the superficial cervical lymph-nodes.

The nerves of the auricle have their origin from very different sources. The anterior portion is supplied by the *auriculotemporal nerve* from the mandibular (see page 203) through the *anterior auricular nerves*, the posterior portion from the *posterior branch of the great auricular nerve* (see page 214). The *auricular branch of the vagus* supplies the bottom of the cavity of the concha as well as the external auditory meatus.

FIG. 821.—A vertical section of the scalp. (Enlarged twelve diameters.)
FIG. 822.—The sweat-glands of the axilla.

The auricle is developed from folds of the embryonic integument in the region of the external aperture of the auditory meatus; that is to say, over the posterior border of the first and the anterior border of the second visceral arch, and becomes evident as early as the fifth week of embryonic life.

THE OLFACTORY ORGAN.

The superior portion of the nasal cavity, termed the *olfactory region*, which is distinguished by its microscopic structure, functions as the olfactory organ (see Vol. II, page 87).

THE GUSTATORY ORGAN.

The gustatory organ also is recognizable, mainly by its microscopic structure, and is located in the papillæ of the mucous membrane of the tongue, mainly in the vallate papillæ (see Vol. II, page 35).

THE EXTERNAL OR COMMON INTEGUMENT.

The *common integument* serves, first, as a covering for the whole body, and, second, as the seat of the sense of touch and of related sensory impressions. A distinction must be made between the true external skin, the *cutis*, and its appendages. At the orifices of the body the integument becomes continuous with the neighboring mucous membrane without any sharp line of demarcation, as, for instance, at the mouth, nose, palpebral fissure, anus, urethra, and female genital organs; no such transition occurring, however, at the orifice of the auditory meatus, since the lining of the external meatus is only a continuation of the integument

The integument consists of three layers, which, named from without inward, are, first, the *epidermis;* second, the *corium;* and third, the subcutaneous, connective, or adipose tissue, the *subcutaneous tela.*

The *epidermis* is the epithelial part of the integument, and, thus also, the origin of all its glandular appendicular structures. It varies greatly in thickness in the different parts of the body, being thickest in the palm of the hand and sole of the foot, very thin on the eyelids, the prepuce, the scrotum, and elsewhere. At the body orifices it becomes continuous with the epithelium of the mucous membranes, and in the colored races its deeper layers are the seat of the pigment formation, as it is also in the more strongly colored regions of the "white" races, such as the scrotum, genitals, anus, nipple region, and the middle line of the abdomen in pregnant women. The further structure of the epidermis is largely microscopical (see the Sobotta-Huber *Atlas and Epitome of Histology*).

The *corium* is grooved on its external surface, that is, on the surface facing the epidermis, these grooves being the *sulci of the cutis*, which are variable in depth, some being shallow and others deeper. In certain regions, as in the palm of the hand and sole of the foot, where they are arranged especially distinctly and regularly, they are separated by small ledges called the *ridges of the cutis*, the sulci and ridges forming peculiar regular figures, whose form and arrangement are

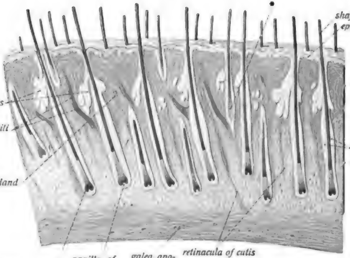

Fig. 821.

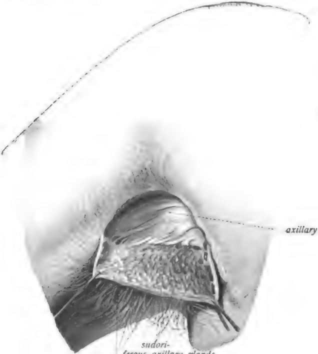

Fig. 822.

variable, though characteristic of each individual (Figs. 827 and 828). The corium, which is formed by a felt-like reticulum of connective-tissue bundles, varies greatly in thickness in different parts of the body, usually corresponding with the thickness of the epidermis. The numerous elastic fibers of the corium give a high grade of elasticity to the integument, and it also possesses smooth muscle tissue, usually in small bundles, visible only on microscopic examination, but forming in some places, as in the tunica dartos of the scrotum (see Vol. II, page 139) and in the mammary areola (see below), a continuous layer.

The *tactile toruli* are minute, cushion-like areas of the volar surface of the hand and the plantar surface of the foot, which are especially rich in sensory nerve-endings.

The *subcutaneous tela* is practically continuous with the corium, since its entire thickness is traversed by large connective-tissue strands of the corium, the *retinacula of the cutis* (Fig. 821). The subcutaneous tela is separated from the tissue lying below it by a usually thin and fascia-like lamina known as the *superficial (general) fascia*. In most parts of the body the subcutaneous tela consists of adipose tissue which forms the so-called *panniculus adiposus*, only certain regions, such as the eyelids, scrotum, prepuce, and auricle, being destitute of it.

At various points there occur beneath the integument mucous sacs which are called *subcutaneous bursæ*, because they lie in the region of the subcutaneous tela. Sometimes they are of large size, as is the case with the *prepatellar subcutaneous bursa*, but usually they are quite small. The following are the principal bursæ which occur: the *premental subcutaneous bursa*, the *subcutaneous bursa of the laryngeal prominence*, the *sacral subcutaneous bursa*, the *acromial subcutaneous bursa*, the *olecranal subcutaneous bursa*, the *subcutaneous bursæ of the medial and lateral epicondyles of the humerus*, the *dorsal metacarpophalangeal* and *dorsal digital subcutaneous bursæ*, the *trochanteric subcutaneous bursa*, the *prepatellar* and *infrapatellar subcutaneous bursæ*, the *subcutaneous bursa of the tuberosity of the tibia*, the *subcutaneous bursæ of the medial* and *lateral malleoli*, the *calcaneal subcutaneous bursa*. There are, in addition, a number of inconstant bursæ, but those mentioned above are the most constant; their locations are indicated by their names.

The Appendages of the Integument.

THE GLANDS OF THE CUTIS.

In the integument there are two kind of glands, differing in form, the glomiform and the sebaceous glands.

The *glomiform glands* are found in almost all parts of the integument in the form of the *sudoriferous glands*. The real secreting portions of the glands are coiled, and, at least in the better-developed sudoriferous glands, lie in the subcutaneous tela, the excretory duct permeating the corium and epidermis to open by a minute orifice, the *sudoriferous pore*. These openings—at least those of the larger glands—can just be recognized by the naked eye, especially upon the ridges of the cutis of the fingers (Fig. 827) and the toes. The sudoriferous glands of the axilla (Fig. 822) attain an especially large size, as do also the glomiform glands of the eyelids known as the *ciliary glands* (glands of Moll) (see page 270), the *circumanal glands*, which are as large as those of the axilla, and are scattered over a zone about 1 to 2 cm. in diameter, surrounding the anus, and the *ceruminous glands* of the external auditory meatus (see page 295).

FIG. 823.—The anterior aspect of the right breast of a pregnant woman.

FIG. 824.—The anterior aspect of the dissected right mammary gland of a pregnant woman.

The skin has been removed with the exception of that of the papilla.

FIG. 825.—The right mammary gland of a pregnant woman; bisected in the sagittal plane.

FIG. 826.—The right mammary gland of a pregnant woman.

A circular strip of the integument has been excised about the nipple (* — cut margins). The integument in the vicinity of the nipple has been reflected toward this structure in order to show the lactiferous ducts.

The *sebaceous glands* (Fig. 821) are almost always in connection with the hair-follicles and are situated in the region of the corium; they produce the *cutaneous sebum*, a secretion rich in fat. The sebaceous glands are entirely absent in those portions of the palm of the hand and the sole which are destitute of hairs, and they are especially large on the ala of the nose, where they occur in connection with very small lanugo hairs, and on the labia minora, where they are independent of hairs. Sebaceous glands also occur on the glans and prepuce of the penis and the red portions of the lips. The tarsal (Meibomian) glands are especially modified sebaceous glands of the eyelids (see page 272).

THE MAMMARY GLAND.

The two *mammary glands* must also be regarded as glands of the integument, since they are really modified sudoriferous glands, which, when in a fully developed and active condition, secrete the milk, *lac*, and, during the first days after birth, the *colostrum*. They are paired glands situated in the skin of the thorax, mainly in the adipose tissue, by which they are surrounded, the varying development of the glands, and especially of the associated subcutaneous adipose tissue, producing a variable degree of fulness of the breasts in different individuals. The *body* of each gland has the form of a flattened hemisphere and consists of fifteen to twenty-four irregularly shaped *mammary lobes*, which are more or less deeply separated by the adipose tissue. Each lobe is again divided into smaller lobules and has a special duct, the *lactiferous duct*, opening upon the nipple.

The *mammary papilla*, or nipple, lies in the middle of a circular, darkly pigmented area of integument, the *mammary areola*. This is distinguished by a lack of fat and by the presence of larger sebaceous glands lying in its periphery, the so-called *areolar glands* (Montgomery's glands), which form small wart-like projections. At the time of lactation and also during pregnancy the pigment of the mammary areola is considerably increased. The papilla itself is cone-shaped, varying individually in length and thickness; it is covered by a very wrinkled, delicate membrane, and is rich in smooth muscle-fibers, which form a layer extending throughout both the papilla and the neighboring portions of the areola. At its apex are the orifices of the lactiferous ducts, which appear as fine openings about 0.5 mm. in diameter, and just before its orifice each duct has a spindle-shaped dilatation, the *lactiferous sinus*.

The mammary gland lies on the level of the third to the sixth or seventh ribs, in the mammary region. The level of the papilla is very variable and usually corresponds to the fourth intercostal space. Laterally, the mammary body has only an ill-defined boundary, and its processes often reach as far as the axillary fossa. It is separated from the pectoralis major by the fascia of that muscle.

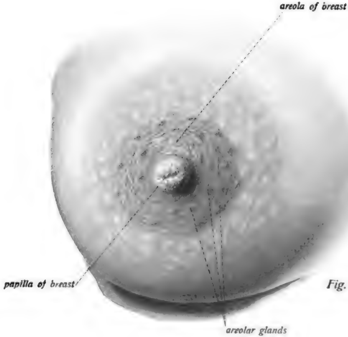

Fig. 823.

Fig. 824.

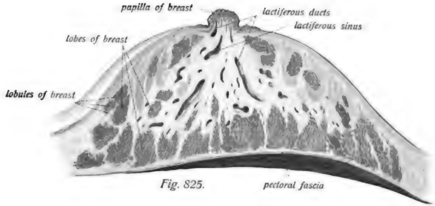

Fig. 825.

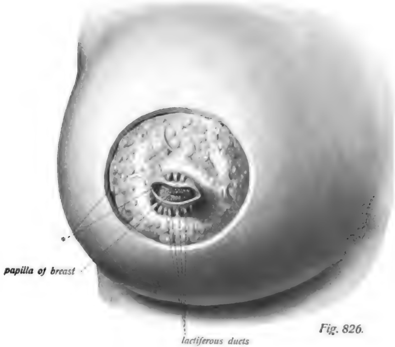

Fig. 826.

Only when active does the gland attain its full size, this condition being first reached toward the end of pregnancy. It occurs in the male in an incompletely developed condition, forming what is termed the *mamma virilis.* Accessory mammary glands and papillæ occasionally occur at various parts of the body, usually in the neighborhood of the normal glands, but occasionally in the axillary fossa or even on the thigh.

The mammary gland derives its bloodvessels from very different sources: External mammary branches arise from the lateral thoracic artery (see page 42); the lateral and medial mammary branches come from the intercostal arteries (see page 53), and numerous mammary branches also pass to the gland from the internal mammary artery. The veins accompany the arteries and their roots anastomose in the areola to form the *mammillary venous plexus.*

The lymphatics of the mammary gland all pass to the axillary lymph-nodes.

The nerves of the mammary papilla and skin, but not of the gland itself, are the lateral and medial mammary rami of the lateral and anterior cutaneous branches of the intercostal nerves (see page 228).

THE HAIRS.

The *hairs* (Fig. 821) are fine, but long, partly very long and thread-like, horny formations of the skin which project freely above the surface by the portion known as the hair shaft or *scapus,* while the portion known as the root or *radix* is obliquely imbedded in the skin itself and is surrounded by the *hair follicle.* At the fundus of the follicle the hair is fastened to the *hair papilla.*

The integument bears two varieties of hairs, the wool or *lanugo hairs* and the stronger body-hairs. The lanugo hair always has the form of very fine hairs, such as those of the eyelids, which can hardly be recognized by the naked eye, partly as somewhat coarser, but always very short, hairs, which are found on almost all portions of the skin where the stronger body hairs do not develop. The only portions of the body entirely without hair are the palm of the hand and sole of the foot, the volar (plantar) surfaces of the fingers and toes, the dorsal surface of the terminal phalanges of the fingers and toes, and partly also the middle phalanges, the glans penis, the inner surface of the prepuce, and the red portion of the lips.

The stronger body hairs are usually distinguishable from the lanugo hairs by their greater, sometimes much greater, thickness, and also by their being more densely crowded and of considerable length. The eyebrows, *supercilia,* eyelashes, *cilia,* the hairs of the nostrils, *vibrissæ,* and the hair in the first portion of the cartilaginous auditory meatus, *tragi,* are short; those of the head, *capilli,* of the beard, *barba,* of the pubic region, *pubes,* and of the axilla, *hirci,* are longer and stronger. The hairs of the pubic and axillary regions are peculiar, and are distinguished, even in straight-haired people, by being decidedly curled.

The hairs often occur in groups, as on the scalp. The curved lines along which the hairs are arranged are known as the *flumina pilorum,* and are especially distinct in the fœtus, and, occasionally, as at the crown of the head, become *vortices.* A crown occasionally occurs in the coccygeal region, the *vortex coccygeus.*

The hairs have a limited duration of life, and after falling out they are usually replaced by new ones. This change is very marked in the cilia, whose life is only one hundred to one hundred and fifty days, while the hairs of the head are said to attain an age of from two to four years.

FIG. 827.—The ridges and sulci of the volar surface of the finger-tip. (Enlarged 2 : 1.)
FIG. 828.—Impression of the ridges and sulci of two fingers.
FIG. 829.—A nail removed from its matrix and viewed from the dorsal surface.
FIG. 830.—A dorsal view of a finger-nail in its natural position.
FIG. 831.—A dorsal view of the finger-nail.
The nail has been bisected by a longitudinal incision and the matrix exposed upon the left side.

Typical sexual differences occur in the growth of hair, as the absence of beard and anal hairs and the sharply outlined growth of hair of the mons pubis in the female.

THE NAILS.

The *nails* (Figs. 829 to 831) are thin, horny, transparent plates which are fastened to the dorsal surfaces of the terminal phalanges of the fingers and toes, and are, therefore, twenty in number. They are strongly curved transversely to the axis of the phalanx, the curve being convex dorsally. The largest part of the nail is free and is known as the *body*, and the thin border which extends beyond the distal end of the phalanx is termed the *free margin*. The posterior thinner portion, the *root*, lies in a fold of the integument, the *ungual fold* (see below), and terminates with a sharp, usually convex border, the *concealed margin*, while the lateral walls, which are also largely contained within the cutaneous folds of the cutis, are known as the *lateral margins*. At the line of transition of the root into the body of the nail, especially in the case of the thumb-nail, there is a whitish, semilunar area, the *lunula*, which represents that part of the area of the formation of the nail which projects beyond the wall of the nail (see below). The convex surface of the nail is smooth while the concave surface is finely ribbed, the horny nail on this surface passing without interruption into the non-cornified germinal layer of the epidermis.

The nail rests by its concave inferior surface upon the *matrix*, which is a part of the integument free from glands and adhering to the dorsal surface of the unguicular tuberosity of the terminal phalanx by strong connective-tissue fibers. On its free surface, facing the inferior surface of the nail, it shows distinct longitudinal ridges, the *ridges of the matrix*. The cutaneous furrow in which the root and the posterior part of the lateral border of the nail are situated is called the *sulcus of the matrix*, and the fold of integument which partly covers the margins of the nail is the *wall*. The body of the nail is closely adherent to the matrix throughout the greater portion of its length, only the distal part of the nail being free on both surfaces.

APPENDIX I.

THE REGIONS OF THE HUMAN BODY.*

IN THE human body there may be distinguished, in the first place, certain main parts, such as the *head*, the *neck*, the *trunk*, and the *extremities;* and the trunk is again divisible into the *thorax*, *abdomen*, and *back* or *dorsum*. The extremities are divided into the *upper* and the *lower extremities*.

* Since the special description of the regions of the human body belongs properly to topographic anatomy, only a short account of them is given here.

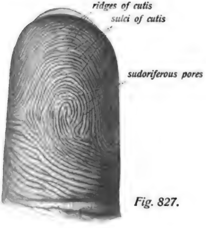

Fig. 827.

Fig. 828.

Fig. 829.

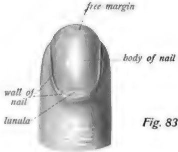

Fig. 830.

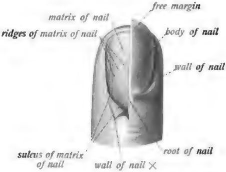

Fig. 831.

The Regions of the Head.—The facial portion of the head is known as the *face*. In the cranial portion there are the *frons*, the *vertex*, the *temples*, the *occiput*, and the *sinciput*.

The region of the forehead is known as the *frontal region*. On either side of this unpaired region there may be recognized as a subdivision, the *supra-orbital region*, corresponding to the eyebrows. On either side of the head are the *temporal regions*, and above these the unpaired *parietal region*, the latter corresponding in its extent to the two parietal bones, while the former corresponds largely to the squamæ of the temporal bones. Behind the parietal region is the *occipital region*, also unpaired; the region about the auricle is the *auricular region*, and the small region behind it, the *mastoid region*, this corresponding to the mastoid portion of the temporal bone.

The Regions of the Face.—The *nasal region* corresponds to the external nose. The *oral region* is the region about the mouth, and is again divided into the *superior* and *inferior labial regions*. At the chin is the *mental region*, which is also unpaired. The (paired) cheek region is called the *buccal region*, and the region about the eyes the *orbital region;* it is also paired, and is again divided into the *superior* and *inferior palpebral regions*. Below the orbital region and bordering medially on the nasal region is the *infra-orbital region*, and also, more laterally, the *zygomatic region*, which extends to the temporal region. The *parotideomasseteric region* lies behind the buccal region and below the zygomatic and temporal regions; its posterior part, which extends back to the superior portion of the sternocleidomastoid region, is called the *retromandibular fossa*.

The Regions of the Neck.—The neck is divided by a line corresponding to the anterior border of the trapezius into the true neck, *collum*, and the *nucha* (*cervix*). The latter contains only the unpaired posterior region of the collum or *nuchal region*, lying below the occipital region, and the *nuchal fovea*, which is a small, triangular depression below the external occipital protuberance.*

The collum is divided by the sternocleidomastoid into two main regions, an unpaired, *anterior region of the neck* and a *lateral region* lying between the borders of the sternocleidomastoid, trapezius, and the clavicle. The portion over the sternocleidomastoid itself is known as the *sternocleidomastoid region*, and the lower portion of this, lying between the two heads of the muscle, is called the *minor supraclavicular region*.

In the lateral region of the neck the depressed area above the clavicle is called the *supraclavicular fossa*, and the region between the clavicle, the inferior border of the inferior belly of the omohyoid, and the posterior border of the sternocleidomastoid is the *omoclavicular trigone*.

The anterior neck region is divided into unpaired and paired subdivisions. The unpaired parts, counted from above downward, are: 1. The *submental region*, lying below the mental region and extending laterally to the anterior belly of the digastric muscle. 2. The *hyoid region*, corresponding to the hyoid bone. 3 The *subhyoid region*, the space between the hyoid bone and larynx. 4. The *laryngeal region*, corresponding to the thyreoid cartilage. 5. The *thyreoid region*, corresponding to the surface of the thyreoid gland. 6. The *suprasternal region*, below the larynx, above the sternum, and medial to the two sternocleidomastoids, the most depressed

* The depression is between the medial borders of the semispinales capitis.

portion of which is called the *jugular fossa*. The paired subdivisions of the lateral neck region are:

1. The *submaxillary*, bounded by the base of the mandible and the two bellies of the digastric muscle.

2. The *carotid fossa*, lying on the anterior border of the upper half of the sternocleidomastoid, bounded superiorly by the posterior belly of the digastric and the stylohyoid, and anteriorly bordering on the hyoid, subhyoid, and thyreoid regions.

The Regions of the Trunk.—To determine the position of the organs of the trunk the following lines, in addition to the intercostal spaces, are employed: the *anterior* and *posterior median lines;* the *sternal line*, parallel to the first, on the lateral border of the sternum; the *mammillary line*, through the middle of the nipple; the *parasternal line*, between the two preceding and parallel to them; the *axillary line* passing from the highest point of the axillary fossa vertically downward; and the *scapular line*, parallel to the posterior median line, through the inferior angle of the scapula. The regions of the trunk are divided into the pectoral, abdominal, and dorsal.

The Pectoral Regions.—In the thorax there is, in the first place, the unpaired *anterior pectoral region*, separated from the paired *lateral pectoral regions* (right and left) by the border of the pectoralis major (anterior axillary fold).

In the anterior pectoral region are the following subdivisions:

The unpaired *sternal region*, corresponding to the surface of the sternal bone, and the *clavicular region*, having the same relation to the clavicle. Below the clavicular is the paired *infraclavicular region*, whose lateral portion, bordering on the deltoid region, is the *deltoideopectoral trigone*, or, since it is often depressed, the *infraclavicular fossa*. On either side, next to the inferior portion of the sternal region, is the *mammary region*, corresponding to the mammary gland in the female and to the sternocostal part of the pectoralis major. Connected with it, inferiorly, is the paired *inframammary region*, which forms the lower end of the thorax and is separated from the abdomen by a transverse line crossing the lower border of the sternum.

The lateral pectoral region is divided into two indistinctly separated portions: the upper *axillary region* with the axillary fossa, and the lower *lateral costal region*. The axillary fossa is bounded by the *axillary folds*, the *anterior axillary fold* corresponding to the border of the pectoralis major and the *posterior axillary fold* to that of the latissimus dorsi.

The Abdominal Regions.—The abdomen is divided by two parallel horizontal lines (an upper one, which connects the lower borders of the costal arches, and a lower one, drawn between the anterior superior iliac spines) into three main regions lying one upon the other: the *epigastric*, the *mesogastric*, and the *hypogastric regions*. In the epigastric region there is an area, corresponding to the infrasternal angle (see Vol. I, page 35), which is usually depressed and is known as the *scrobiculus cordis*. Lateral to the epigastric region on either side, below the inframammary region, is the *hypochondriac region*, corresponding to the costal arches.

The mesogastric region is divided into the middle, unpaired *umbilical region*, which includes the part about the umbilicus and the median portion of both recti abdominis muscles, and the *lateral abdominal region*, which borders superiorly on the hypochondriac region and is bounded inferiorly by the iliac crest.

The hypogastric region is divided into a middle, unpaired *pubic region* with the *mons pubis*, and paired *lateral inguinal regions*, whose lower limit is the inguinal ligament.

The Dorsal Regions.—The dorsum embraces, besides the true back, also the gluteal, anal, and perineal regions. The unpaired *median dorsal region* extends from the inferior end of the nuchal region to the superior end of the sacral region and corresponds to the width of the vertebral column. The *sacral region* is the direct continuation of the median dorsal region and corresponds to the dorsal surface of the sacral bone.

On either side, lateral to the median dorsal region, is the *scapular region*, the extent of which is determined by the scapula; and above the scapular region is the *suprascapular region*, which extends laterally to the axillary region, while below it is the *infrascapular region*, the lateral boundary of which, toward the lateral pectoral and hypochondriac regions, is formed by the lateral border of the latissimus dorsi and its inferior boundary by the twelfth rib. On either side, next to the medial border of the scapula and the median dorsal region, is a narrow band which, with the adjacent portion of the preceding region, forms the unpaired *interscapular region.*

Below the infrascapular region, on either side, next to the median dorsal region, is the *lumbar region*, which extends down to the crest of the ilium. The *coxal region* is separated from the lumbar and lateral abdominal regions by the iliac crest, while the lateral (superior) border of the gluteus maximus separates it from the *gluteal region*. This almost corresponds with the large gluteal muscles, but extends down only to the gluteal sulcus (see Vol. I, page 232), which forms the boundary between the buttock and thigh. Laterally, the gluteal region borders upon the *trochanteric region*. At the lower end of the trunk is the unpaired *perineal region*, which borders on the sacral region superiorly, and on the gluteal regions laterally. The shape of this region almost corresponds to that of the pelvic outlet, and it is divided into a posterior *anal* and an anterior *urogenital region;* the latter, including the *pudendal region*, being occupied by the external genital organs.

The Regions of the Upper Extremity.—The upper extremity is divided into the upper arm or *brachium*, the forearm or *antibrachium*, and the hand or *manus*, and the hand is again divided into *carpus*, *metacarpus*, and *digits*.

The usually somewhat flattened region which forms the summit of the shoulder is called the *acromial region*, and that corresponding to the deltoid muscle is the *deltoid region*, which extends into the scapular region of the dorsum. The true brachium is divided into *anterior*, *medial*, *posterior*, and *lateral brachial regions*, and at the elbow, *cubitus*, there are also *anterior*, *medial*, *posterior*, and *lateral cubital regions*. The most depressed spot of the cubital region is called the *cubital fossa*, and the part of the posterior cubital region corresponding to the olecranon of the ulna is the *olecranal region*.

In the forearm, as in the upper arm, there is a *volar*, *ulnar*, *posterior*, and *radial antibrachial region*.

The hand is divided into the *volar* and *dorsal* regions, and in the digits there are the *volar regions*, the *dorsal regions*, and the *unguicular regions*, which bear the nails. The thumb is called the *pollex;* the forefinger, *index;* the middle finger, *third* or *medial digit;* the ring finger, the *fourth* or *annular digit;* the little finger, the *fifth digit* or *minimus*.

The Regions of the Lower Extremity.—In the leg there is the thigh or *femur*, whose

upper boundary is, anteriorly, the inguinal ligament and, posteriorly, the gluteal sulcus; it is followed by the knee or *genu*, then the leg or *crus*, and the foot or *pes*, the latter being divided into *tarsus*, *metatarsus*, and *digits*.

The portion of the thigh which corresponds to the greater trochanter and borders medially on the gluteal region is called the ***trochanteric region***, and there are an ***anterior***, a ***medial***, a ***posterior***, and a ***lateral femoral region***. The part of the anterior femoral region which lies immediately below the inguinal ligament is called the ***subinguinal region***.* In the knee there is an ***anterior*** and a ***posterior region;*** in the middle of the latter is the ***popliteal fossa;*** and opposite it, in the anterior region, is the ***patellar region***, corresponding to the patella.

The crus is divided into an ***anterior***, ***medial***, ***posterior***, and ***lateral crural region***. The upper part of the posterior crural region, which corresponds to the calf, is called the ***sural region***. The regions of the ankles are known as the ***malleolar regions*** (***medial*** and ***lateral***), and the parts behind the ankles are the ***retromalleolar regions*** (medial and lateral).

In the foot there is a ***dorsal*** and a ***plantar region***, and also a ***calcaneal region***. In the toes there are ***dorsal digital*** and ***unguicular regions***. The big toe is called ***hallux;*** the little toe, the ***fifth digit*** or ***minimus***.

APPENDIX II.

GENERAL REMARKS CONCERNING THE STRUCTURE AND EARLY DEVELOPMENT OF THE HUMAN BODY.

FROM its development, as well as from its internal organization, the trunk, together with the head, which lies in direct continuity with it, is to be regarded as the main portion of the body, the limbs or extremities being merely appendicular structures which do not contain any visceral structures, but, in addition to the general integument the body, consist only of the skeleton and muscles, with the nerves and vessels belonging to them.

The viscera of the human body are primarily two parallel, longitudinal canals which are so placed in the embryo that one, the *medullary canal*, is found on the dorsal side of the body, the other, the *alimentary canal*, on the ventral side. Between the two, as the precursor of the much later, bony skeleton, is the *chorda dorsalis*, which, with the exception of a few insignificant remains (see Vol. I, page 110) is completely degenerated in the adult. Both canals are enclosed by the body wall, which consists of integument, skeleton, and musculature, and surrounds both visceral canals so that each lies in a canal-like cavity, the medullary canal, in the ***neural canal*** or *neural cavity*, and the alimentary canal, in the visceral *canal* or *cavity*.

The medullary canal, early in the development, shows a club-shaped enlargement of its head portion which represents the brain, and, corresponding to this, the neural canal also shows a corresponding expansion which, like the remaining part of the neural canal, is later bounded by the osseous skeleton, becoming the cranial cavity and the vertebral canal. The visceral canal also partly acquires a bony wall in the form of the ribs, and, in the course of its development, becomes very much wider than the neural canal and does not enclose the alimentary canal closely, but forms a relatively wide space in which all the outgrowths of the embryonic alimentary canal,

* The femoral triangle (see Vol. I, page 216) is also part of the anterior femoral region.

such as the respiratory and portions of the urogenital organs, as well as the glands belonging to the alimentary canal, have a place. Neither does the visceral canal adapt itself to the extensive variations in caliber of the alimentary canal, nor does it elongate proportionally with it, since its elongation is determined by that of the neural canal. Consequently the intestines become greatly coiled in the visceral canal. In addition to the digestive, respiratory, and urogenital organs, also a part of the vascular system, the heart, finds its place in the visceral canal.

The **primary foundation of the human body** * is the fertilized ovum, the products of whose division, the blastomeres, form a hollow vesicle upon which (as in the development of vertebrates with eggs rich in yolk) is a relatively small region, the embryonic area, which is the starting-point for the development of the embryo. In the embryonic area a streak-like structure appears, the **primitive streak**, from whose anterior end a process known as the head process of the primitive streak grows out. This represents the first appearance of the embryonic body, and in it the germ layers, which are differentiated in the region of the primitive streak, form the first organs of the later embryo.

The germ layers are at first three layers of embryonic cells which are connected with one another at the anterior end of the primitive streak. They are an outer layer or **ectoderm** (ectoblast), a middle layer or **mesoderm** (mesoblast), and an inner layer or **entoderm** (entoblast); and from them, by modifications which they undergo in the region of the head process of the primitive streak and, later, of the embryonic body, all parts of the body are developed. From the external germ layers are derived the entire epidermis with all the epidermal structures, such as the cutaneous glands, hairs, nails, and the lens of the eye, the whole central and probably also the peripheral nervous system, and the higher organs of sense, such as the retina of the eye, the epithelium of the membranous labyrinth, and the olfactory and gustatory epithelium. From the entoderm are derived the epithelium of the digestive organs, including all the digestive glandular structures, the epithelium of the respiratory organs and its glands, and the epithelium of the urinary bladder. The mesoderm is divided by a differentiation of its elements, the so-called mesodermic somites and the lateral plates, into three parts: The one part furnishes the epithelium of the serous cavities of the body and of the greater part of the urogenital apparatus (lateral plate); the second part the entire striated musculature of the body, this being formed from the myotomes of the mesodermic somites. The third part is also called mesenchyme and arises from the mesodermic somites, as well as from the lateral plates. It is the source of all the supporting tissue of the body, together with the smooth muscle tissue. All the varieties of connective or supporting tissue, adipose tissue, loose and compact connective tissue, tendons and fascia, the corium of the integument, all bones and cartilages, the lymph-nodes, spleen, etc., are developed from the mesenchyme, as are also the vascular and lymphatic systems.

The first organs that can be recognized in the embryonic germ layers are the medullary and alimentary canals. They are formed by a folding of the external and internal germ layers, respectively, and by their formation the fundamental shape of the human body (see above) is determined. The folding of the medullary canal is preceded by a thickening of the ectoderm to form the medullary plate.

The alimentary canal at first is closed at both the upper and lower ends (see also Vol. II,

* For details consult text-books of embryology.

pages 21 and 57). The upper blind end, separated from the buccal cavity (see Vol. II, page 21) by the pharyngeal membrane, is known as the head or branchial gut, and forms during the third week of development four or five so-called pharyngeal pockets, that is, lateral recesses of the wall of the embryonic pharynx which grow toward the branchial pouches, which are corresponding depressions of the external skin. Each two branchial and visceral pouches are separated from one another by a part of the cartilaginous visceral skeleton of the embryo known as a *branchial* or *visceral arch*. The majority of the branchial and pharyngeal pockets disappear, later, almost completely, the first only being retained in part to form the middle ear (see page 294) and the external auditory meatus. From the epithelium of the lower ones portions of the thyreoid gland and the thymus glands develop (see Vol. II, pages 106 and 109); and from the branchial arches the hyoid bone (see Vol. I, page 73), the styloid process of the temporal bone, and the auditory ossicles, malleus and incus, and possibly the stapes also (see page 289), are developed.

The visceral canal is lined by a part of the middle germ layer, the so-called lateral plates. These enclose a cavity, the primitive visceral cavity or **cœlom**, which is single at first and only later a division into the thoracic and abdominal cavities, that is to say, into the four serous cavities of the body, the two pleural cavities, the pericardial, and the peritoneal cavity,* takes place by the formation of the diaphragm.

The other portions of the middle germ layer, the mesodermic somites, appear in the embryo in segmented form, that is to say, in two rows which lie on either side, next to the middle line. In the first place the body musculature is developed from them, but retains its distinct segmental arrangement throughout life only in the intercostal muscles and in the deeper layers of the dorsal musculature. This primary segmented arrangement of the muscle masses gives rise to a secondary segmentation of the mesenchymatous representatives of the axial skeleton, and, therefore, of the subsequent vertebral column.† The segmental arrangement of the musculature also gives rise to a segmentation of the nerves arising from the central nervous system, an arrangement which is continued into the region of the head.

The extremities are relatively late in appearance, and arise as small outgrowths of the embryonic integument, into which, later on, the muscle and skeletal tissues grow. At first they are unjointed appendages, the joints appearing rather late.

* The serous cavity of the tunica vaginalis propria is constricted off from the peritoneal cavity.

† The intervals between the vertebræ do not correspond to the intervals, but to the centers, of the mesoblastic somites. Toward the central portion of the primitive myotome is also the motor nerve growing out of the central nervous system, so that after the development of the skeletal tissue the nerve comes to lie in the interval between two vertebræ (intervertebral foramen).

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